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ADAPTIVE TROPOSPHERIC RANGE CORRECTION

Teledyne Micronetics

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ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
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This report describes a technique for obtaining accurate adaptive range correction for very low elevation angles utilizing radar as a sensor. A two step procedure is utilized. First, the radar obtains refractive bending information from tracking cooperative targets whose angular positions and range are accurately known. This information is thus used to estimate the range correction for uncooperative targets.

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The technique consists of defining the range delay as a sum of three terms of which the first term involves integration over the refractive profile, whereas, the other two terms are expressable in terms of parameters directly measured by the radar. It also turns out that the integral of the first term can be accurately evaluated using a "standard profile" determined by the radar.

This technique was evaluated using 96 radiosonde profiles. Maximum range error estimates were about 1.5 meters with typical values of less than 50 cm.

EVALUATION

F30602-76-C-0384

1. This is the Final Report on the contract which over the period from November 1976 to August 1977 investigated the feasibility of an adaptive technique for estimating the tropospheric range error of targets with very low elevation angles, using radar as a sensor. The report describes a technique, which is carried out in two phases, for obtaining accurate adaptive range correction. The first is the calibration procedure in which the radar obtains the refractive bending information from tracking of cooperative targets whose positions are known accurately. Second is the range correction procedure for noncooperative target. Using the "standard refractivity profile" which can be determined from the information obtained in the calibration phase, the range error is expressed as the sum of a term which involves integration over the refractivity profile and two terms which can be given in terms of parameters directly measured by the radar and the surface reflectivity. The technique was found to be capable of providing highly effective range correction with accuracies of better than two meters all the way down to the zero elevation angle if the radar is assumed to be capable of angular accuracy of 0.1 milliradian.

2. The above work should be of considerable value since the accurate determination of the range correction is a matter of vital military interest in connection with the reliable operation of the radar and communication systems of various types.

Larry E Telford

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SUMMARY OF IMPORTANT RESULTS

The adaptive tropospheric range correction technique developed under this program is capable of providing highly accurate radar range measurements at all angles of elevations down to grazing incidence.

The underlying concept is the utilization of the radar as a sensor to measure refractive errors of cooperative target such as navigational satellites whose true positions are well known. The discrepancy between the true and apparent elevation angle provides refractive information necessary for range correction for noncooperative targets.

The range error is expressed as a sum of three terms DR1, DR2 and DR3. DR2 and DR3 are completely defined in terms of parameters measured directly by the radar. The evaluation of DR1 requires the knowledge of the refractive profile which in general is not known. It turns out, however, that DR1 can be accurately evaluated using an equivalent "standard" profile which is completely defined in terms of the measured value of surface refractivity and the measured value of refractive bending at elevation angle of 20 milliradians which is known from refractive calibration with cooperative satellites.

This technique was evaluated using 96 randomly chosen radiosonde profiles from Eglin AFB. Only three out of the 96 cases had errors exceeding one meter with the maximum value of 1.53 meter. Over 85% of error fell between -24 and +74 cm. with over 1/3 of error less than 50 cm. An error analysis indicates that an additional error of 40 cm. may be expected due to the stipulated angular accuracy of the radar of 0.1 mr.

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The conclusion is that the technique described in this report is capable of providing highly effective tropospheric radar range correction with typical accuracies of better than two meters at very low elevation angles where tropospheric range delays are typically on the order of 100 meters and may on occasions reach several hundred meters in the presence of strong refractive gradients.

FOREWORD

This is the Final Report under Contract No. F30602-76-C-0384. The Teledyne Micronetics Program Manager was Dr. Steven Weisbrod. Other contributors to this effort were Lee A. Morgan and Philip A. Hicks. The program was administered by Dr. Edward E. Altshuler, RADC/EEP, Hanscom AFB, MA. 01731.

Special thanks are due to Dr. Koichi Mano of RADC/EEP for his careful review of theoretical derivations, and to Mr. Larry E. Telford, also of RADC/EEP, for his cooperation in making available to us the Eglin Air Force Base profiles which were used for the evaluation of this technique.

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1.0 INTRODUCTION

1.1 Background Information

The purpose of this effort was to devise an adaptive technique for tropospheric range corrections accurate to within six feet using the radar itself as a sensor. The standard techniques, which are based on the observed values of surface refractivity, work fairly well at elevation angles above two or three degrees but can lead to large errors at lower elevation angles, particularly if there should exist a strong refractive gradient.

For the purpose of this effort, it was assumed that the radar is a fairly large ground based state-of-the-art instrument capable of tracking targets with an apparent angular accuracy of about 0.1 mr. and range of one or two meters. It was also assumed that the radar could track cooperative satellites either in the passive or active mode and that the true position of the satellites was known to within 100 meters.

The approach which was selected for the study stipulates that the radar would routinely track cooperative satellites so that the refractive bending of the troposphere would be known at the time when a non-cooperative target was to be tracked. We also assumed that the ionospheric refractive effects were either negligible or that an adequate correction could be made from top and bottom ionosonde data to correct for satellite position. Another assumption in this study was that the uncooperative target was above the troposphere but below the ionosphere. We believe that the technique described in this paper can be extended to targets within the troposphere but this has not yet been done.

1.2 General Description of the Approach

A study of a large number of refractive profiles by the National Bureau of Standards* had indicated that refractive profiles above one kilometer may be represented by two exponential profiles: one that starts with the value of refractivity of N_1 at one kilometer above the surface and decreases to $N = 105$ at 9 Km, and the second which starts at 9 Km with $N = 105$ and decreases to $N = 1$ at 39 Km. Above 39 Km, we assumed that refractive effects are negligible.

It turns out that the range error DR may be represented as a sum of three terms:

$$DR = DR1 + DR2 + DR3$$

The terms DR2 and DR3 are expressed in terms of parameters which are directly measureable by the radar and do not require any information on the profile structure. The term DR1 is an integral over the profile but fortunately it is quite insensitive to the details of the structure.

The way we handled the evaluation of DR1 was to assume that the profile had a linear decrease from a known surface value of N_o to some as yet unspecified value of N_1 at one kilometer above the surface and then exponentially decreased to 105 N units at 9 Km and to 1 N unit at 39 Km. This equivalent profile, which we called the "standard profile", was therefore uniquely defined in terms of N_o and N_1.

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* B.R. Bean and E. J. Dutton, "Radio Meteorology", NBS Monograph 92, March 1966, pp. 59-68.

In order to define the correct procedure to identify the effective value of N_1 from observed refractive bending of cooperative satellites to be used in standard profile, we resorted to an extensive computer study of various refractive profile models representing the full range of reasonable values of N_o, N_1 and refractive gradients in the first kilometer above the surface. It soon became apparent that if we matched the value of refractive bending, γ, computed from the model at an elevation angle β_o anywhere between 10 and 30 milliradians, with the angle β_o anywhere between 10 and 30 milliradians, with the corresponding value of γ from the standard profile with the same value of N_o as the model, that particular standard profile would give excellent values of DR1 over all values of β_o all the way down to grazing incidence. It is interesting to note that the effective value of N_1 as determined from the standard profile frequently differed considerably from the "true" value of N_1 as defined by the model. Strong gradients near the surface tended to lower the effective value of N_1 while elevated gradients tended to increase it. Nevertheless, the computed DR1 using the effective value of N_1 gave excellent results.

Since there appears to be no critical dependence on the choice of β_o, we selected β_o = 20 mr. as the "reference value" of β_o at which γ would be measured operationally to define the equivalent N_1.

To facilitate the computation of the effective value of N_1, we computed γ for 160 standard profiles representing the full range of N_o and N_1 values. We then used least square polynomial fit to express N_1 as a function of measured N_o and γ at β_o = 20 mr.

The crucial test of this technique was made using 96 representative radiosonde profiles taken at Eglin AFB over one year. The range delays computed from the actual profiles were compared with those using the standard profile based on the computed value of γ at 20 mr. The result showed typical differences of less than 50 cm. with only one case under ducting conditions where the difference was about 1.5 meters.

We can, therefore, conclude that the use of an equivalent standard profile to compute DR1 and the use of observed values to compute DR2 and DR3 provide a highly effective method to correct radar tropospheric range errors to within one or two meters down to zero elevation angle.

2.0 THEORY

2.1 Basic Equations

In this section, we will give the overview of theoretical results. In order to make this section more readable, we delegated mathematical details to appendices.

In Appendix A, it is shown that the range error DR may be expressed as a sum of three terms

$$DR = DR1 + DR2 + DR3 \qquad 2\text{-}1$$

where

$$DR1 = \int_{\rho=\rho_o}^{\rho=\rho_T} N(\rho)\, d\,(\rho \sin \beta) \times 10^{-6} \qquad 2\text{-}2$$

$$DR2 = \gamma N_o \times 10^{-6}\, \rho_o \cos \beta_o$$

$$DR3 = (A + B)\, \rho_o \cos \beta_o$$

$$A = (\alpha^2 \tan \beta_T - \delta^2 \tan \beta_o)/2$$

$$B = (\alpha^3 + \delta^3)/6 - N_o\, \alpha \times 10^{-6}$$

$N(\rho)$ = refractive profile

ρ = distance from the earth's center

β = local elevation angle of the ray. Subscripts o and T will be used to express the values of ρ and β at the surface and at the target

γ = refractive bending

N_o = surface refractivity

δ = refractive error

α = $\gamma - \delta$

= 0 at astronomical distances

Figure 1 in Appendix A illustrates the geometry of refractive effects.

DR1 is the dominant contribution to DR. Its value varies typically from about 80 meters at $\beta_o = 0$ to about 30 meters at $\beta_o = 50$ mr. It is the only term whose value directly depends on the shape of the refractive profile. It turns out that it is relatively insensitive to the profile structure and it can be accurately determined using the "standard" profile described in Section 1.2.

Terms DR2 and DR3 are expressable in terms of parameters which are presumably available at the radar site as a result of routine tracking of cooperative satellites and measurements of N_o. For transtropospheric distances, DR2 is independent of range but DR3, which is a function of δ, depends on the target range. Typical values of DR2 range from about 30 meters at $\beta_o = 0$ to about 10 meters at $\beta_o = 50$ mr. Values of DR3 nominally range from near 0 at $\beta_o = 0$ to a minimum of about -5 meters at $\beta_o \simeq 20$ mr. and gradually increase to 0 with the increasing β_o. However, in the presence of strong gradients, value DR3 may acquire a large positive value near $\beta_o = 0$ and may become the dominant term at grazing incidence.

2.2 Evaluation of DR1

In general, DR1 cannot be evaluated in closed form. A convenient way is to represent the profile in terms of a number of linear segments and perform the integration piecewise. In Appendix B, it is shown that DR1 is given by

$$DR1 = F_1 + F_2 \qquad 2\text{-}3$$

where $$F_1 = -N_o \rho_o \sin \beta_o \qquad 2\text{-}4$$

$$F_2 = \sum_{i=o}^{M-1} \frac{(N_i - N_j)\ \rho_i\ \rho_j\ (A_i^{\ 2} + A_i\ B_i + B_i^{\ 2}) \times 10^{-6}}{1.5\ \ \rho_o \cos\ \beta_o\ (A_i + B_i)} \qquad (2\text{-}5)$$

$j = i + 1$

M = number of "significant" heights at which values of N are defined

$A_i = \sin\ \beta_j \cos\ \beta i$

$B_i = \sin\ \beta_i \cos\ \beta_j$

In evaluating DR1, we utilized the "standard" profile which was defined in terms of measured value of N_o and an effective value N_1 the value of N at 1 kilometer height.

The "standard" profile is represented as follows:

$$\begin{aligned} N(h) &= N_o - DN{\cdot}h && 0 \leq h \leq 1 \text{ Km} \qquad (2\text{-}6)\\ &= N_1 \exp(a_1(h-1)) && 1 \leq h \leq 9 \text{ Km}\\ &= 105 \exp(a_2(h-9)) && 9 \leq h \leq 39 \text{ Km}\\ &= 0 && h > 39 \text{ Km}\\ DN &= N_o - N_1 &&\\ a_1 &= \ln(105/N_1)/8 &&\\ a_2 &= -.155132 && \end{aligned}$$

In this study, we assumed that the surface value was essentially at sea level. For elevated locations N_1 is defined as the value of N at one kilometer above the local surface. Values of N_9 and N_{39} remain 105 and 1 N units respectively and represent values at 9 and 39 Km above sea level. Consequently, for elevated locations, the standard profile will need to be redefined accordingly.

In evaluating DR1 using standard profiles, we incremented heights in 1 Km steps from 0 to 9 Km and in 3 Km steps from 9 to 39 Km.

2.3 Evaluation of Effective N_1

Evaluation of N_1 is performed semiempirically. First, we generated 160 standard profiles with values of N_o ranging from 250 to 400 in increments of 10 and DN ($DN = N_o - N_1$) from -20 +170 also in increments of 10. Then for different values of β_o ranging from β_o = 5 mr. to 30 mr. in steps of 5 mr. we computed γ. In Appendix B, it is shown that

$$\gamma = 2\sum_{i=o}^{M-1} \frac{(N_i - N_j) \times 10^{-6}}{\tan \beta_i + \tan \beta_j} \qquad (2\text{-}7)$$

where $j = i + 1$

and M = number of significant heights in the profile (For the standard profile M = 20)

Since the object here was to estimate N_1 from the observed value of refractive bending γ at some apparent elevation angle β_o , we used the computed values of γ to set up a fifth order Least Square Polynomial in the form

$$DN = \sum_{i}^{5} \sum_{j}^{5} b_{ij} \gamma^{i} (N_o - 300)^{j} \qquad (2\text{-}8)$$

for a selected value of β_o

Using test profiles, we experimented with different values of β_o and concluded that while the apparent values of N_1 will vary slightly with β_o the final results in computing DR1 were very good over the range of β_o from 10 to 30 mr. with the overall results probably best in the vicinity of β_o = 20 mr. We, therefore, selected β_o = 20 mr. as the elevation angle at which γ should be measured to obtain the effective value of N_1.

Table I gives values of γ for various values of N_o and DN. **Table** 2 gives fifth order least square coefficients of DN (γ) for various values of N_o. Table 3 gives fifth order least square coefficients for the coefficients of DN (γ) as a function of N_o.

It is this last set of coefficients which is actually used to compute DN for arbitrary values of N_o and γ at β_o = 20 mr.

To use these coefficients we proceed as follows. Using the measured value of N_o, we compute a_i, the ith power coefficient

$$a_i = \sum_{j=0}^{5} b_{ij} (N_o - 300)^j \quad (N_o \text{ in N units}) \quad (2\text{-}9)$$

where b_{ij} are the tabulated values in Table 3. The value of i is shown at the top of each group.

Using computed values of a_i, we next compute DN

$$DN = \sum_{i}^{5} a_i \gamma^i \quad (\gamma \text{ in mr.}) \qquad (2\text{-}10)$$

and $$N_1 = N_o - DN$$

Once N_1 is defined, we compute DR1 as explained in Section 2.2.

TABLE 1

Values of γ in the Standard Profile for Various Combinations of N_0 and DR at the Elevation Angle of 20 mr.

GAMMA FOR B0=20 MR.

DN:N0	250	260	270	280	290	300	310	320
-20	5.00	5.29	5.57	5.86	6.16	6.45	6.75	7.05
-10	5.17	5.46	5.74	6.03	6.33	6.62	6.92	7.22
0	5.34	5.63	5.92	6.21	6.50	6.80	7.09	7.39
10	5.52	5.81	6.10	6.39	6.68	6.98	7.27	7.57
20	5.71	5.99	6.28	6.57	6.87	7.16	7.46	7.76
30	5.90	6.19	6.47	6.76	7.06	7.35	7.65	7.95
40	6.10	6.38	6.67	6.96	7.25	7.55	7.85	8.15
50	6.30	6.59	6.87	7.16	7.46	7.75	8.05	8.35
60	6.52	6.80	7.09	7.38	7.67	7.96	8.26	8.56
70	6.74	7.02	7.30	7.59	7.89	8.18	8.48	8.78
80	6.96	7.25	7.53	7.82	8.11	8.41	8.71	9.01
90	7.20	7.48	7.77	8.06	8.35	8.64	8.94	9.24
100	7.45	7.73	8.01	8.30	8.59	8.89	9.18	9.48
110	7.70	7.98	8.27	8.55	8.85	9.14	9.44	9.74
120	7.97	8.25	8.53	8.82	9.11	9.40	9.70	10.00
130	8.26	8.53	8.81	9.10	9.39	9.68	9.98	10.28
140	8.55	8.83	9.10	9.39	9.68	9.97	10.26	10.56
150	8.86	9.13	9.41	9.69	9.98	10.27	10.57	10.86
160	9.19	9.46	9.73	10.01	10.30	10.59	10.88	11.18
170	9.54	9.80	10.07	10.35	10.63	10.92	11.21	11.51

DN:N0	330	340	350	360	370	380	390	400
-20	7.35	7.66	7.96	8.28	8.59	8.90	9.22	9.54
-10	7.52	7.83	8.14	8.45	8.76	9.08	9.40	9.72
0	7.70	8.00	8.31	8.62	8.94	9.25	9.57	9.89
10	7.88	8.18	8.49	8.80	9.12	9.43	9.75	10.08
20	8.06	8.37	8.68	8.99	9.30	9.62	9.94	10.27
30	8.25	8.56	8.87	9.18	9.50	9.82	10.14	10.46
40	8.45	8.76	9.07	9.38	9.70	10.01	10.34	10.66
50	8.66	8.96	9.27	9.59	9.90	10.22	10.54	10.87
60	8.87	9.17	9.48	9.80	10.11	10.43	10.75	11.08
70	9.09	9.39	9.70	10.02	10.33	10.65	10.97	11.30
80	9.31	9.62	9.93	10.24	10.56	10.88	11.20	11.53
90	9.55	9.85	10.16	10.48	10.79	11.11	11.44	11.76
100	9.79	10.10	10.41	10.72	11.04	11.36	11.68	12.01
110	10.04	10.35	10.66	10.97	11.29	11.61	11.94	12.26
120	10.31	10.61	10.92	11.24	11.55	11.88	12.20	12.53
130	10.58	10.89	11.20	11.51	11.83	12.15	12.47	12.80
140	10.87	11.17	11.48	11.80	12.12	12.44	12.76	13.09
150	11.17	11.47	11.78	12.10	12.42	12.74	13.06	13.39
160	11.48	11.79	12.10	12.41	12.73	13.05	13.38	13.70
170	11.81	12.12	12.43	12.74	13.06	13.38	13.70	14.03

TABLE 2

Fifth Order Least Square Coefficients
for N_1 as a Function of γ at β_o = 20 mr.
at Specified Values of N_o

LEAST SQUARE COEFFICIENTS

DN(GM) FOR B0=20 MR.

LSC:N0	250	260	270	280
0	-4.99219E 2	-5.40413E 2	-5.83673E 2	-6.29105E 2
1	1.44470E 2	1.51543E 2	1.58879E 2	1.66499E 2
2	-1.28397E 1	-1.34488E 1	-1.40603E 1	-1.46792E 1
3	7.45308E -1	7.78459E -1	8.08791E -1	8.37339E -1
4	-2.67714E -2	-2.78467E -2	-2.86333E -2	-2.92351E -2
5	4.33828E -4	4.53891E -4	4.63295E -4	4.66294E -4

LSC:N0	290	300	310	320
0	-6.76816E 2	-7.26906E 2	-7.79489E 2	-8.34673E 2
1	1.74424E 2	1.82665E 2	1.91239E 2	2.00159E 2
2	-1.53093E 1	-1.59516E 1	-1.66085E 1	-1.72805E 1
3	8.64788E -1	8.91408E -1	9.17567E -1	9.43375E -1
4	-2.97179E -2	-3.01126E -2	-3.04506E -2	-3.07444E -2
5	4.65464E -4	4.62123E -4	4.57360E -4	4.51672E -4

LSC:N0	330	340	350	360
0	-8.92564E 2	-9.53281E 2	-1.01695E 3	-1.08368E 3
1	2.09429E 2	2.19065E 2	2.29080E 2	2.39475E 2
2	-1.79672E 1	-1.86694E 1	-1.93881E 1	-2.01215E 1
3	9.68828E -1	9.94043E -1	1.01914E 0	1.04396E 0
4	-3.09986E -2	-3.12233E -2	-3.14272E -2	-3.16045E -2
5	4.45309E -4	4.38574E -4	4.31703E -4	4.24614E -4

LSC:N0	370	380	390	400
0	-1.15358E 3	-1.22683E 3	-1.30344E 3	-1.38368E 3
1	2.50259E 2	2.61458E 2	2.73029E 2	2.35044E 2
2	-2.08696E 1	-2.16353E 1	-2.24092E 1	-2.32026E 1
3	1.06851E 0	1.09307E 0	1.11681E 0	1.14075E 0
4	-3.17581E -2	-3.19021E -2	-3.20013E -2	-3.21020E -2
5	4.17391E -4	4.10316E -4	4.02761E -4	3.95565E -4

TABLE 3

Fifth Order Least Square Coefficients to Compute Coefficients of DN(γ) Polynomials for Arbitrary Values of (N_o - 300)

LEAST SQUARE COEFFICIENTS FOR N0

LSC:PWR	0	1	2
0	-7.26907E 2	1.82666E 2	-1.59519E 1
1	-5.13179E 0	8.40512E -1	-6.49246E -2
2	-1.24504E -2	1.65941E -3	-7.07408E -5
3	-1.81910E -5	2.19383E -6	-2.02312E -7
4	-8.33619E -9	-6.25539E -9	2.34014E -9
5	-6.06875E-12	1.62758E-11	-8.22828E-12

LSC:PWR	3	4	5
0	8.91445E -1	-3.01158E -2	4.62237E -4
1	2.63066E -3	-3.57379E -5	-4.43082E -7
2	-2.56507E -6	2.98847E -7	-7.44401E -9
3	3.85820E -8	-3.88042E -9	1.50317E-10
4	-4.41782E-10	4.22630E-11	-1.70153E-12
5	1.74875E-12	-1.74939E-13	7.20707E-15

Note: The above set of coefficients was obtained by the least square fit of the corresponding power coefficients in Table 2 with (N_o - 300) as the dependent variable.

2.4 Evaluation of DR2 and DR3

Evaluation of DR2 poses no problem since γ is a known function of β_o which has been established through cooperative satellite observations.

$$DR2 = \gamma N_o \times 10^{-6} \rho_o \cos \beta_o \qquad (2\text{-}11)$$

Evaluation of DR3 is somewhat more involved since it is also a function of refractive bending error, δ , which is not directly known. δ can be readily computed by a very rapidly converging iterative procedure from the measured values of β_o, γ and range R.

The procedure is as follows:

Set the initial value of δ equal to γ, which is the correct value at astronomical distances. Next estimate the great circle distance θ using

$$\sin \theta = \frac{R \cos (\beta_o - \delta)}{(\rho_o{}^2 + R^2 + 2R \rho_o \sin (\beta_o - \delta))^{1/2}} \qquad (2\text{-}12)$$

Using the estimated value of θ, compute a new value of δ from

$$\delta = \beta_o + \arctan ((A + B/\tan \theta)/n_o) \qquad (2\text{-}13)$$

$$A = \sin \gamma - \tan \beta_o \cos \gamma$$

$$B = \tan \beta_o \sin \gamma - N_o \times 10^{-6} - \gamma^2/2$$

$$n_o = 1 + N_o \times 10^{-6}$$

Using the updated value of δ, repeat the last two steps. It has been found that two iterations are sufficient to compute δ to within a few microradians and the value of DR3 to within one centimeter even under near ducting conditions where DR3 may be hundreds of meters.

$$\begin{aligned} DR3 &= (A + B)\,\rho_o \cos \beta_o \\ \text{where} \quad A &= (\alpha^2 \tan \beta_T - \delta^2 \tan \beta_o)/2 \qquad (2\text{-}14) \\ B &= (\alpha^3 + \delta^3)/6 - N_o\,\alpha \times 10^{-6} \\ \alpha &= \gamma - \delta \end{aligned}$$

All angles are in radians.

Derivation of above equations are detailed in Appendix C.

3.0 ANALYSIS OF RADIOSONDE DATA

3.1 Description of Experimental Data

Theoretical procedures for range correction were checked using randomly selected radiosonde data from Eglin AFB in Florida. The data consisted of eight day and night samples taken during the first five days of each month over a period of one year. Five of the 96 samples represented ducting conditions.

Since only a few of the radiosonde profiles reached the height of 39 Km, it was necessary to augment those profiles which did not reach the 39 Km height by adding additional data points. This was done by taking the last measured value and appending to it an exponential decrease of refractivity which decayed to the value of N = 1.0 at 39 Km. It should be noted that the estimated value of N at 39 Km from the profiles which exceeded 39 Km and six more which exceeded 38.3 Km was 1.05 $\pm$ .07 N units. This verifies that the assumed value of N = 1.0 at 39 Km was valid. The bias in the estimated value of DR1 using N at 39 Km of 1.00 rather than 1.05 varies from about -5 cm. at β_0 = 0 to -3 cm. at β_0 = 50 mr. for value of DN of 100.

3.2 Results of Computer Analysis

For the purpose of the computer analysis, it was assumed that the radar would measure the same $\gamma(\beta_0)$ as would be computed from the observed radiosonde profile. The "measured" value of γ at β_0 = 20 mr. was then used to obtain the effective value of N_1 which in turn defined the equivalent profile that was used to compute DR1. Since DR2 and DR3 are defined in terms of parameters measured directly by the radar and are not explicit functions of the profile, the range error was then defined as the difference between the "true" value of DR1 computed from the measured radiosonde profile and the estimated value of DR1 computed from the "standard" profile based on the effective value of N_1. These computations were carried out exactly as described in Section 2.0.

Results of the computer analysis of the 96 profiles are tabulated in Appendix D. These profiles are arranged in 8 groups of 12 representing each month of the year. The eight profiles of each group represent samples taken during the first five days of the month. Half of these samples were taken at noon and the other half at midnight. The profiles are labeled by day, month, hour, number of points in the profile.

Since the following discussion is based on that data, the reader is advised to thumb through this appendix in order to gain some familiarity with the various parameters. The format explanation of the computer printout is given at the beginning of the appendix.

The parameter which is of main interest is the range error, tabulated in the last column. Perusal of the computer results show that the typical value of the error is less than 50 cm. Only three out of 96 profiles had errors exceeding 100 cm. with the maximum value of 153 cm.

It will also be noticed that these errors in general do not appear to be a strong function of the elevation angle over the range from 0 to 50 mr. Table 4 shows the distribution of errors for the various values of β_0. The last column labeled "Av" is the error averaged over the elevation angles from 0 to 50 mr.

Examination of Table 4 shows that over 85% of errors lie between -24 and +74 cm. with over 1/3 of errors between 25 and 49 cm. This positive bias is partly due to the fact

TABLE 4

ERROR DISTRIBUTION TABLE

Range Error - Cm.	ELEVATION ANGLE β_o IN MR.						
	0	10	20	30	40	50	Av*
-74 to -50	0	0	3	3	0	0	0
-49 to -25	2	8	6	6	8	5	7
-24 to -0	7	11	18	17	10	9	10
0 to 24	24	21	19	18	23	28	24
25 to 49	43	39	32	34	38	38	38
50 to 74	13	13	13	13	12	12	12
75 to 99	2	2	2	3	3	2	3
100 to 124	0	1	1	1	1	2	1
125 to 150	0	1**	2	1	1	0	1
Total	91***	96	96	96	96	96	96

* "Av" is the value of the range error averaged over all values of β_o from 0 to 50 mr.

** The actual value of this point was 153 cm. and it represents the maximum error that was observed.

*** At $\beta_o = 0$ five profiles showed ducting.

that at 39 Km we used the value of N of 1.0 rather than 1.1. If we used the value of 1.1, there would be an increase in the estimated value of DR1 of about 10 cm. which would remove a substantial portion of the bias.

Comparison of profiles 4APR0051 and 5MAY0055 is of special interest. The values of surface refractivity for the two profiles are 313.3 and 313.4 and the range delays at β_o = 0 mr. differ by more than 100 meters. The difference in DR1 is only about 3 meters and it is pretty well corrected by the slight difference in observed γ at 20 mr. The main contributions to the large discrepancy of the range error are DR2 and DR3 terms which are functions of the parameters which are directly observable at the radar site. A more detailed analysis of the profile structure showed that the profile 4APR0051 had a surface refractive gradient of 152 N units/Km. (157 will cause ducting). This near ducting condition manifests itself with a large increase of γ at β_o = 0 mr. but not at β_o = 20 mr. which is used to define the standard profile and DR1. Thus, we can conclude that the major contributions to the total range under near ducting conditions will come from DR2 and DR3 and, therefore, this technique should provide excellent corrections even under those conditions.

3.3 Error Sensitivity

This technique of range error correction is based on the stipulation that the radar is capable of providing angular information accurate to within 0.1 mr. A computer analysis was therefore carried out to estimate what would happen if an error of 0.1 mr. is introduced in γ.

An increase of 0.1 mr. in the reference value of γ at β_o = 20 mr. will cause an increase in the value of apparent N_1 of about 4 N units. This will cause decrease in the estimated value of DR1 of about 80 cm. at β_o = 0 and about 25 cm. at β_o = 50 mr. A corresponding increase of 0.1 mr.

in the observed value of γ will cause an increase in the sum of DR2 and DR3 of about 40 cm. at $\beta_o = 0$ and about 15 cm. at $\beta_o = 50$ mr. The net error increase is, therefore, about 40 cm. at $\beta_o = 0$ and about 10 cm. at $\beta_o = 50$ mr.

Since the observed maximum error was about 1.5 meters, we can conclude that the uncertainty of $\pm$ 0.1 mr. in the observed value of γ may push the maximum error to about 2 meters.

4.0 OPERATIONAL PROCEDURES FOR RANGE ERROR CORRECTION

4.1 General Description of Operational Procedure

It is envisioned that the operational procedure will be divided into two phases, calibration and target tracking, which would be carried out alternately. During the calibration phase, the radar will routinely track cooperative satellites to obtain the best updated information on the structure of the troposphere around the radar. In the tracking phase, the radar will track an uncooperative target and using the information from the calibration phase will make the best estimate of the range error.

If real time correction is required, the calibration phase must precede the tracking phase. However, if the range correction is not required in real time, the calibration phase could be made before or after, or both, to get the best estimate of the tropospheric structure closest to the time when observations on the target were made.

4.2 Calibration With Cooperative Satellites

The following information will be required for calibration:

1. Real-time monitoring of surface refractivity
2. Computer with stored library of suitable cooperative satellites with updated ephemerides.
3. Time reference to coordinate satellite position with radar observations.
4. Table of the 36 coefficients to define the standard profile in terms of measured N_o and γ at β_o = 20 mr. (See Section 2.3).

The calibration procedure will be as follows:

1. Compute the great circle distance θ between the radar and the subsatellite point using the Law of Cosines

$$\cos\theta = \cos\lambda_1 \cos\lambda_2 + \sin\lambda_1 \sin\lambda_2 \cos\phi$$

where λ_1, λ_2 are colatitudes of the two points and ϕ is the difference in longitudes.

An alternate form of the Law of Cosines which would avoid possible computer round off errors caused by working with cosines of small angles is

$$\sin^2(\theta/2) = \sin^2((\lambda_1-\lambda_2)/2) + \sin\lambda_1 \sin\lambda_2 \sin^2(\phi/2)$$

2. Compute β_T from Snell's Law

$$n_o\, \rho_o \cos\beta_o = n_T\, \rho_T \cos\beta_T$$

(See Section 2.2 or Appendix A for explanation of symbols).

Here again, the round off errors can be minimized by using an alternate form of Snell's Law

$$\tan^2(\beta_T/2) = (S + Q)/(1 - S + Q)$$

where $S = \sin^2(\beta_o/2)$

$Q = (H - \rho_o (N_o - N_T) \times 10^{-6})/2\, n_o\, \rho_o$

H = height of the satellite

3. Compute γ from the relationship

$$\gamma = \beta_o + \theta - \beta_T$$

4. Define γ as a function of β_o by tracking satellites over the entire range of β_o of interest.

5. Using best estimate of γ at $\beta_o = 20$, compute DN using the 36 coefficients as described in Section 2.3 and define the standard profile which will be used to compute DR1.

This calibrating procedure will presumably be carried out routinely before and after uncooperative target tracking and will be used to provide the best real time definition of the standard profile.

4.3 Range Correction Procedures

Range correction of non-cooperative targets will be carried out as follows:

1. From observed value of β_o and the standard profile, compute DR1 as outlined in Section 2.2.

2. Using known value of γ from the measured value of β_o, compute DR2 as shown in Section 2.4.

3. Using measured value of range R and the assumed value of refractive error δ equal to the value of γ as defined by the measured value of the apparent elevation angle β_o, compute angular distance θ using Eq. 2-12 in Section 2.4.

Obtain an updated value of δ using Eq. 2-12 and repeat this procedure getting an updated value of θ from Eq. 2-12 and a new and final value of δ using Eq. 2-13. Using this final value of δ, evaluate DR3 using Eq. 2-14 as described in Section 2.4.

4. Compute range error DR from

$$DR = DR1 + DR2 + DR3.$$

5. As a *final refinement*, we could use the corrected value of range R decreased by the calculated value of DR to recalculate DR3 as indicated in Steps 3 and 4. In extreme situations, where DR is several hundred meters, this step may change the value of δ by a few tens of microradians and the value of DR3 by a few tens of centimeters.

5.0 EXTENSIONS OF THE RANGE ERROR TECHNIQUES

5.1 Present Limitations

The study which was performed here assumed that the radar was at sea level, the target height was above the troposphere and that the frequency was sufficiently high so that the ionospheric effects were negligible. It is reasonable to speculate that these constraints are not necessary and that the technique could be extended accordingly.

In the following subsections, procedures will be described which should lead to the removal of these constraints. However, it should also be emphasized that before such procedures are adapted, their validity should be verified through computer simulation studies.

5.2 Extension to Higher Site Altitudes

The National Bureau of Standards' study indicates that the standard atmosphere concept is valid if the value of N_1 is redefined as the value of refractivity at one kilometer above the surface. However, values of N at 9 Km and 39 Km are referenced to the height above sea level. Consequently, this technique should work satisfactorily if the standard atmosphere for evaluation of DR1 is defined accordingly. The main change would be in the values of the 36 coefficients which are used to compute DN in terms of observed N_0 and γ at $\beta_0 = 20$ mr.

5.3 Extensions to Target Heights in the Troposphere

It should be possible to extend this technique to target heights well within the troposphere and probably all the way down to one kilometer above the surface. The procedure would be essentially the same. Using observed γ at $\beta_0 = 20$ mr., we define effective N_1 which in turn defines the standard profile. The integration of DR1 would be performed to the observed height of the target. The term F_1 (Eq. (2-4), Section 2.2) of DR1 would need to be modified by the addition of $N_T \rho_T \cdot \sin \beta_T$ since N_T would no longer be equal to zero. The values of DR2 and DR3 would be modified by using values of $\gamma(\beta_o)$ which are reduced by the contribution to γ between the target height and the top of the troposphere as defined by Eq. (2-7), Section 2.3.

5.4 Ionospheric Correction

It is assumed that the targets are above the troposphere but below the ionosphere. Consequently, the ionospheric refraction would enter only in measuring γ on transionospheric cooperative targets. At frequencies above 100 MHz, the Appleton-Hartree equation may be simplified to define the ionospheric refractivity as

$$N_i = -(f_p/f)^2 \times 10^6/2$$

where f = signal frequency

and f_p = plasma frequency

$= (N_e\, e^2/m\, \varepsilon_o)^{1/2}/2\pi$

N_e = electron density per cubic meter

e = electron charge

$= 1.6 \times 10^{-19}$ coulombs

m = electron mass

$= 9.1 \times 10^{-31}$ kg

ε_o = permittivity of free space

$= 8.854 \times 10^{-12}$ farads/meter

Since the ionospheric refractive bending at microwave frequencies is very small and inversely proportional to the square of frequency, an adequate correction, if neccessary, could be obtained from the bottom and top side ionosonde data in the general vicinity of the radar site.

The procedure for γ is identical to that for γ in the troposphere except it should be noted that the ionospheric refractivity, N_i, is a negative number. The ionospheric γ can then be subtracted from the total to obtain the γ for the troposphere*.

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*For more complete discussion of ionospheric refractivity, see "Simple Methods for Computing Tropospheric and Ionospheric Effects on Radio Waves" by S. Weisbrod and L.J. Anderson, Proceedings of the IRE, October 1959, pp 1770-1777.

6.0 CONCLUSIONS

The concept of breaking up the range error into three terms DR1, DR2 and DR3 of which only DR1 is dependent on the profile structure but relatively insensitive to the details of the profile structure has been demonstrated to provide a very effective range correction. The effective value of N_1 as deduced at β_o = 20 mr. sometimes differs considerably from the true value of N_1 but because of certain self-compensating features between the observed γ at 20 mr. and effective value of N_1, the standard profile defined by N_o and the effective value of N_1 gives highly accurate values of DR1. Over 95% of errors were less than one meter and the maximum observed error was about 1.5 meters. Since DR2 and DR3 are evaluated in terms of parameters measured directly by the radar, which was assumed to provide assumed accuracy of 0.1 mr., the total error in range is essentially equal to the error in estimating DR1 from the standard profile.

The distribution of errors showed a positive bias of about 25 centimeters. A substantial portion of this bias can be attributed to the assumed value of N = 1.0 at 39 Km in the standard profile. Experimental data indicates that the value of 1.1 would have been a better choice and the value of 1.2 would tend to give values of N between 9 and 20 Km, which were more representative of observed values at these heights. We, therefore, believe that the value of N = 1.2 at 39 Km would distribute the observed errors more nearly around zero and in effect would cause virtually all errors to be less than one meter.

Under near ducting conditions, the main increase in the range delay is due to terms DR2 and DR3. The standard profile continues to provide excellent estimates of DR1 and, therefore, this technique has been demonstrated to provide high accuracy all the way to the grazing incidence even under near ducting conditions.

We can, therefore, conclude that if the radar is capable of angular accuracy of 0.1 mr., the technique developed in this program will provide range accuracies of better than two meters all the way down to the zero elevation angle.

7.0 RECOMMENDATIONS

The technique for the range correction has been estimated at sea level stations and for assumed target heights above troposphere. We have reasons to believe that similar techniques will be applicable to radar sites at higher elevations and to target heights within the troposphere.

We would, therefore, recommend that additional studies using radiosonde data from other locations be carried out and computer evaluations be made for target heights in the lower troposphere.

This technique should also be extendable for targets within or above the ionosphere at UHF and lower microwave frequencies where ionospheric retardation will be significant. The extension of this technique to ionospheric retardation should be investigated.

Consideration should also be given to an experimental verification of this technique. A possible approach would be to use a radar at Eglin AFB in Florida and a radiosonde balloon could be launched off Florida Keys and the tracking could be done through multilateration from nearby sites in Southwestern Florida. Since the tracking would be done at high elevation angles, adequate tropospheric corrections could be made from the available radiosonde data and surface measurements. Optical tracking could be utilized to increase the tracking accuracy.

APPENDIX A
RANGE ERROR FORMULATION

The fundamental expression for the range error, DR, is

$$DR = \int_S n dS - \int_{S_o} dS_o \qquad \text{(A-1)}$$

where n is the index of refraction and S and S_o are the true (refracted) and geometric (straight line) paths respectively as shown in Figure 1. A trivial rearrangement of equation (A-1) yields

$$DR = \int_S N dS \times 10^{-6} + \left\{ \int_S dS - \int_{S_o} dS_o \right\} \qquad \text{(A-2)}$$

where $N = (n-1) \times 10^{+6}$. This form separates the range error into a refractive term and a geometric term (in brackets). The refractive term is dominant but the geometric term represents a significant contribution at low angles and cannot be neglected.

Both equations A-1 and A-2 involve the difference of large nearly equal numbers and are therefore not well suited to numerical evaluation. An alternative form can be derived in the following fashion. We will use Snell's law for spherically stratified media and the Law of Sines

$$n\rho \cos \beta = \text{constant} \qquad \text{(A-3)}$$

$$\rho \cos \eta = \text{constant} \qquad \text{(A-4)}$$

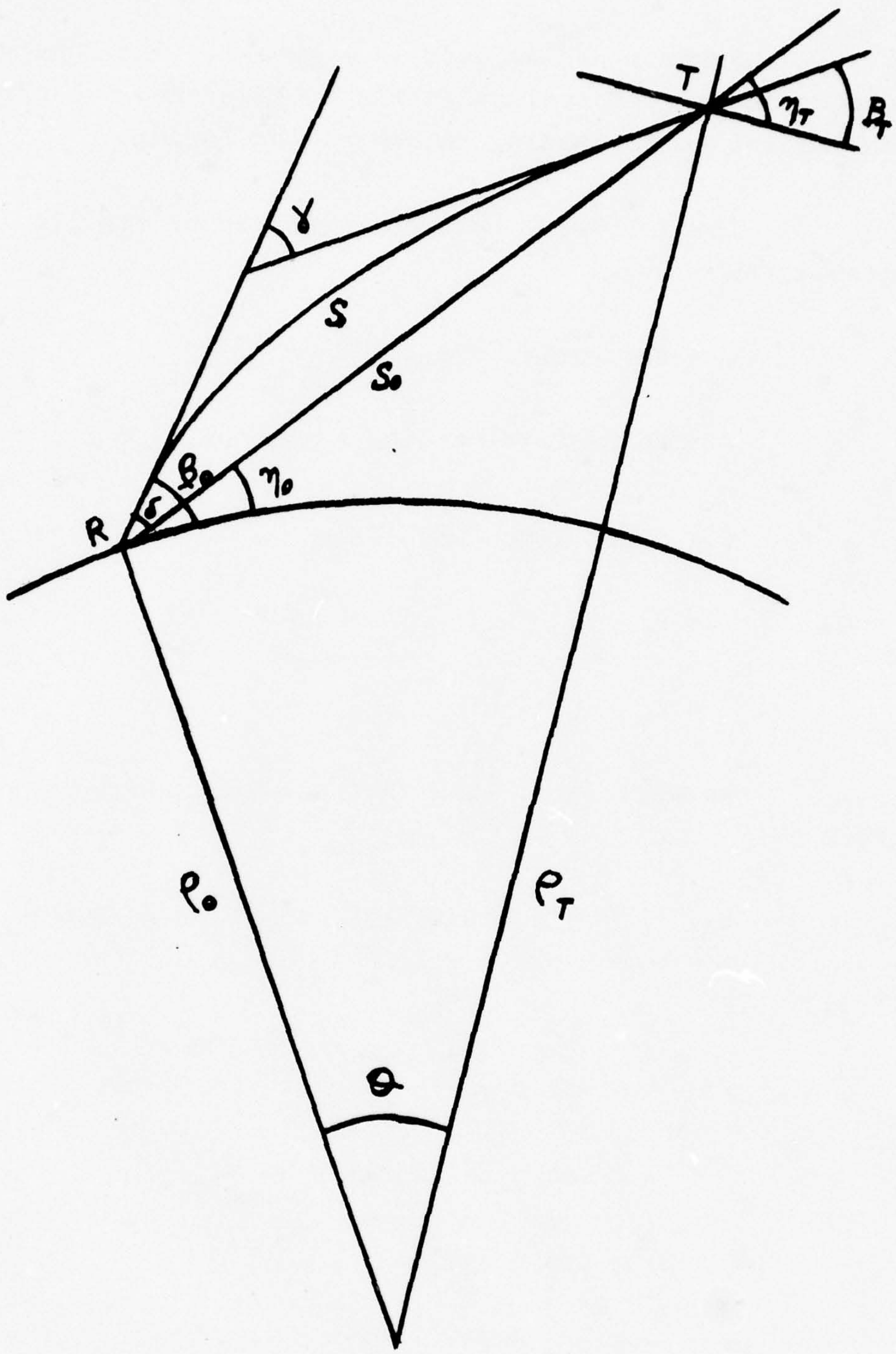

Figure 1. Path Geometry for Refracted and Unrefracted Rays.

Symbols are defined in Figure 1. The subscript o denotes the surface values at the receiver and subscript T denotes the corresponding values at the target.

The following relationships can be readily established

$$\delta = \text{refractive error} \equiv \beta_o - \eta_o \qquad \text{A-5}$$

$$\gamma = \text{refractive bending} = \eta_T - \beta_T + \delta$$

$$\theta = \text{great circle distance}$$

$$= \eta_T - \eta_o$$

$$= \beta_T - \beta_o + \gamma$$

We will first show that the unrefracted path S_o is given by

$$S_o = \int_R^T d(\rho \sin \eta) = \rho_T \sin \eta_T - \rho_o \sin \eta_o \qquad \text{A-6}$$

Proof:

$$dS_o = \rho \sec \eta \, d\theta$$

$$= \rho \sec \eta \, d\eta \text{ (since } \theta = \eta - \eta_o)$$

$$= \rho \cos \eta \sec^2 \eta \, d\eta$$

$$= \rho \cos \eta \, d(\tan \eta)$$

$$= d(\rho \cos \eta \tan \eta) - \tan \eta \cdot d(\rho \cos \eta)$$

$$= d(\rho \sin \eta) - \tan \eta \, d(\rho_o \cos \eta_o)$$

$$= d(\rho \sin \eta)$$

In a similar fashion we will next show that for the refracted distance S

$$\int_S n\,dS = \int_R^T n\,d(\rho \sin \beta) + \gamma n_o \rho_o \cos \beta_o \qquad \text{A-7}$$

Proof:

$$ndS = n\rho \sec \beta \, d\theta$$

$$= n\rho \sec \beta \, d\beta + n\rho \sec \beta \, d\gamma \quad (\text{since } \theta = \beta - \beta_o + \gamma)$$

$$= d(n\rho \sin \beta) + n\rho \sec \beta \, d\gamma$$

(omittted steps are identical to those for dS_o)

$$= n\,d(\rho \sin \beta) + \rho \sin \beta \, dn + n\rho \sec \beta \, d\gamma$$

We next note that*

$$d\gamma = -\frac{1}{n} \cot \beta \, dn$$

Substituting for dn we get

$$ndS = nd(\rho \sin \beta) + n\rho(\sec \beta - \sin \beta \tan \beta)d\gamma$$

$$= nd(\rho \sin \beta) + n\rho \cos \beta \, d\gamma$$

$$= nd(\rho \sin \beta) + n_o \rho_o \cos \beta_o \, d\gamma$$

*For the derivation of this equation see for instance "Radio Meteorology" by B.R. Bean and E. I. Dutton, NBS Monograph 92, p. 87.

Using the relationships we derived above, we can now write

$$DR = \int_S n dS - \int_{S_o} dS_o$$

$$= \int_S (1+N(\rho)x10^{-6})\ d\ (\rho \sin \beta) + \int_S (1+N_o x10^{-6}) \rho_o \cos \beta_o d\gamma$$

$$- \int_{S_o} d(\rho \sin \eta) \qquad \text{(A-8)}$$

Since the end points of paths S and S_o coincide at $\rho = \rho_o$ and $\rho = \rho_T$, we can rearrange A-8 and write

$$DR = DR1 + DR2 + DR3 \qquad \text{(A-9)}$$

where

$$DR1 = \int_S N\ (\rho) x10^{-6}\ d\ (\rho \sin \beta)$$

$$DR2 = \gamma N_o \times 10^{-6}\ \rho_o \cos \beta_o$$

$$DR3 = \int_S d\ (\rho \sin \beta) - \int_{S_o} d\ (\rho \sin \eta) + \gamma\ \rho_o \cos \beta_o$$

$$= \rho_T\ (\sin \beta_o - \sin \eta_T) - \rho_o\ (\sin \beta_o - \sin \eta_o) +$$

$$\gamma \rho_o \cos \beta_o. \qquad \text{(A-10)}$$

But $\eta_o = \beta_o - \delta$

and $\eta_T = \beta_T + (\gamma - \delta) = \beta_T + \alpha$

where $\alpha = \gamma - \delta$

Substituting for η_o and η_T in A-10 and using Snell's Law and small angle approximations for α and δ, we get

$$DR3 = (A + B)\ \rho_o \cos \beta_o \tag{A-11}$$

where

$$A = (\alpha^2 \tan \beta_T - \delta^2 \tan \beta_o)/2$$

$$B = (\alpha^3 + \delta^3)/6 - (N_o - N_T) \times 10^{-6}\ \alpha(1 - (\alpha/2) \tan \beta_T)$$

$$\simeq (\alpha^3 + \delta^3)/6 - (N_o - N_T)\alpha \times 10^{-6}$$

$$= (\alpha^3 + \delta^3)/6 - N_o\alpha \times 10^{-6}$$

for transtropospheric targets.

At astronomical distances, α goes to zero.

APPENDIX B

EVALUATION OF DR1 AND γ

In evaluating both DR1 and γ, linear variation of the refractive index was assumed between the "significant" heights at which the index of refraction was defined

$$N(\rho) = N(\rho_i) + k_i \, h \times 10^6 \qquad \text{(B-1)}$$

where k_i = refractive gradient in the i^{th} layer

= constant

= $(N_j - N_i) \times 10^{-6}/(\rho_j - \rho_i)$

where subscripts i and j refer to the i^{th} and the j^{th} significant height;

$j = i + 1$

ρ = distance from the earth's center.

In Appendix A, equation (A-10), DR1 was defined as

$$DR1 = \int_S N(\rho) \times 10^{-6} \, d(\rho \sin \beta)$$

Integration by parts results in

$$DR1 = F1 + F2$$

where

$$F1 = N(\rho) \times 10^{-6} \, \rho \sin \beta \Big|_{\rho=\rho_o}^{\rho=\rho_T} \qquad \text{(B-2)}$$

$$= -N_o \times 10^{-6} \, \rho_o \sin \beta_o$$

for transtropospheric targets

and

$$F2 = -\int k(\rho) \, \rho \sin \beta \, d\rho \qquad \text{(B-3)}$$

To evaluate this integral, we will break it up into a number of segments with a constant refractive gradient.

Snell's Law states

$$n\rho \cos \beta = n_o \rho_o \cos \beta_o = n_i \rho_i \cos \beta_i = \text{constant} \qquad \text{(B-4)}$$

Using (B-4), we get for sin β

$$\begin{aligned} \sin^2 \beta &= 1 - Q_i^{-2} \cos^2 \beta_i \\ &= Q_i^{-2} (\sin^2 \beta_i + Q_i^2 - 1) \end{aligned} \qquad \text{(B-5)}$$

where $Q_i = (n\rho)/(n_i \rho_i)$

if we define $h = \rho - \rho_i$ and $n = n_i + k_i h$ and note that $h \ll \rho_i$, we can express

$$Q_i^2 - 1 \simeq a_i h$$

where $a_i = 2(k_i \rho_i + 1)/\rho_i$ (B-6)

We can, therefore, write

$$\sin \beta = (n_i \rho_i / n\rho) (\sin^2 \beta_i + a_i h)^{1/2} \qquad \text{(B-7)}$$

Substituting in (B-3) and neglecting n_i/n

$$F_2 = \sum_{i=0}^{M-1} k_i \rho_i \int_0^{H_i} (\sin^2 \beta_i + a_i h)^{1/2} \, dh \qquad \text{(B-8)}$$

where $H_i = \rho_j - \rho_i$

$j = i + 1$

and M = number of significant heights
Subscript o refers to the surface values and to the gradient of the first layer.

Carrying out the integration, we get

$$F_2 = -\sum_{i=o}^{M-1} \frac{k_i \rho_i}{1.5 a_i} \left[(\sin^2 \beta_i + a_i H_i)^{3/2} - \sin^3 \beta_i \right] \qquad \text{(B-9)}$$

(B-9)

where $H_i = \rho_j - \rho_i$

Neglecting n_i/n results in an error of less than half a centimeter.

Using (B-7) and Snell's Law, we note

$$\begin{aligned} \sin^2\beta_i + a_i H_i &= (n_j \rho_j / n_i \rho_i)^2 \sin^2 \beta_j \\ &= \cos^2\beta_i \sin^2 \beta_j / \cos^2 \beta_j \qquad \text{(B-10)} \end{aligned}$$

For convenience, we will define

$$A_i = \sin \beta_j \cos \beta_i \qquad \text{(B-11)}$$

$$\beta_i = \sin \beta_i \cos \beta_j$$

Using B-10 and B-11, we can write

$$(\sin^2\beta_i + a_i H_i)^{3/2} - \sin^3 \beta_i = (A_i^3 - B_i^3)/\cos^3 \beta_j \qquad \text{(B-12)}$$

and

$$a_i H_i = (A_i^2 - B_i^2)/\cos^2 \beta_j \qquad \text{(B-13)}$$

Substituting in (B-9), and noting that $\rho_j \cos \beta_j = \rho_o \cos \beta_o$ and $k_i H_i = -(N_i - N_j) \times 10^{-6}$, we get

$$F_2 = \sum_{i=0}^{M-1} \frac{(N_i - N_j) \times 10^{-6} \rho_i \rho_j (A_i^2 + A_i B_i + B_i^2)}{1.5 \rho_o \cos \beta_o (A_i + B_i)} \qquad \text{(B-14)}$$

which together with equation (B-2) defines DR1.

Computation of γ is carried out in a similar fashion by approximating the refractive profile by linear segments.

Refractive bending γ is given by*

$$d\gamma = -k(\rho) \cot \beta \, d\rho/n \qquad \text{(B-15)}$$

From (B-7) and Snell's Law, we get

$$\cot \beta = \cos \beta_i \, (\sin^2 \beta_i + a_i h)^{-1/2} \qquad \text{(B-16)}$$

Substituting in B-16) and neglecting n

$$= -\sum_{i=o}^{M-1} k_i \int_0^{H_i} \cos \beta_i \quad (\sin^2 \beta_i + a_i h)^{-1/2} \, dh$$

$$= -\sum_{i=o}^{M-1} \frac{2k_i \cos \beta_i}{a_i} \left[(\sin^2 \beta_i + a_i H_i)^{1/2} - \sin \beta_i\right] \qquad \text{(B-17)}$$

Using (B-12) and (B-13) and simplifying, we get

$$\gamma = \sum_{i=o}^{M-1} \frac{2(N_i - N_j) \times 10^{-6}}{\tan \beta_i + \tan \beta_j} \qquad \text{(B-18)}$$

Equation (B-18) was used to compute γ in Table 1.

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*B.R. Bean and E.J. Dutton, "Radio Meteorology", N.B.S. Monograph 92, March 1966, Section 3.12, pp 82-87.

APPENDIX C

EVALUATION OF DR3

In Section 2.4, it was stated that in tracking non-cooperative targets only β_o, $\gamma(\beta_o)$, and R are known. The evaluation of DR3 requires that we also know the refractive error δ. The method for computing involves a rapidly converging iterative procedure where the initial value of δ is set equal to γ and an estimate is made of angular distance θ using equation (2-12). This value of θ is used to compute a new value of δ using equation (2-13). This updated value of θ is then used in equation (2-12) and the process is repeated. It was found that at most two iterations are sufficient to rpovide an estimate of DR3 accurate within one centimeter.

Equation (2-12) is very simply derived from Figure 1 in Appendix A using the Law of Cosines to compute ρ_T and the Law of Sines to compute sin θ. It should be noted that the free space slant range S_o in Figure 1 is equivalent to range R in equation (2-12). Using the triangle formed by ρ_o, ρ_T and S_o, we get

$$\rho_T^2 = \rho_o^2 + R^2 + 2\rho_o R \sin \eta_o \qquad \text{(C-1)}$$

and

$$\sin \theta = R_o \cos \eta_o / \rho_T \qquad \text{(C-2)}$$

Substitution of (C-2) in (C-1) yields equation (2-12)

$$\sin \theta = \frac{R \cos \eta_o}{\left[\rho_o^2 + R^2 + 2\, \rho_o R \sin \eta_o\right]^{1/2}} \qquad \text{(C-3)}$$

Equation (2-13) which is used to compute δ is obtained as follows:

From Figure 1 in Appendix A, the following relationships are obtained

$$\delta = \beta_o - \eta_o \tag{C-4}$$

where η_o is the true elevation angle

$$\beta_T = \beta_o + \theta - \gamma \tag{C-5}$$

$$\eta_T = \eta_o + \theta \tag{C-6}$$

From Snell's Law and the Law of Sines

$$n_o \rho_o \cos \beta_o = n_T \rho_T \cos \beta_T \tag{C-7}$$

$$\rho_o \cos \eta_o = \rho_T \cos \eta_T \tag{C-8}$$

Dividing (C-8) by (C-7) and using (C-5) and (C-6), we get

$$n_o \cos \beta_o \cos(\eta_o + \theta) = \cos \eta_o \cos(\beta_o + \theta - \gamma) \tag{C-9}$$

where n_o is the ratio of the index of refraction at the surface to that at the target. For targets above the troposphere, which is assumed here, n_o is the surface value of the index of refraction.

Expanding (C-9) and approximating $\cos \gamma$ by $1-\gamma^2/2$ to cancel 1 in $n_o = 1 + N_o \times 10^{-6}$, we get

$$-n_o \tan \eta_o = A + B \cot \theta \tag{C-10}$$

where $A = \sin\gamma - \tan\beta_o \cos\gamma$

and $B = \tan\beta_o \sin\gamma - N_o \times 10^{-6} - \gamma^2/2$

Substituting for η_o in (C-4), we get equation (2-13)

$$\delta = \beta_o + \arctan((A + B/\tan\theta)/n_o) \qquad \text{(C-11)}$$

APPENDIX D

RESULTS OF RADIOSONDE DATA ANALYSIS

This appendix contains computer analyses of 96 radiosondes from Eglin Air Force Base.

For the purpose of this analysis, it was assumed that the radar would measure the refractive bending based on the radiosonde data. The estimate of the range error is based on these "measured" values by the radar.

These profiles are arranged in 12 groups representing each month of the year. The eight profiles of each group represent samples taken during the first five days of each month. Half of these samples were taken at noon and the other half at midnight.

Each page contains analyses of four profiles. The format is as follows.

The top line of each analysis identifies the profile and some of its characteristics:

1. Profile identification: day-month-hour (00 = midnight, 12 = noon) and the number of points in the profile

NO	=	Surface refractivity
GMR	=	"measured" γ at β_o = 20 mr.
DN	=	Estimated value of DN (DN = NO - N1 where N1 = refractivity at 1 km above the surface)
DNP	=	"Measured" or the "true" value of DN as interpolated from the radiosonde profile
N9P	=	The "true" value of refractivity at 9 km above sea level. (The assumed value is 105 N units)

The second line of each analysis identifies the tabulated entries below:

BO	=	Measure elevation angle of the target
GM	=	Refractive bending γ. (This value is presumably known as a function of β_o from satellite calibration)
DR1P	=	"True" value of DR1 computed from the profile
DR1S	=	Value of DR1 computed from the standard profile
DR2	=	DR2 (See Section 2)
DR3	=	DR3 for target height of 39 km
DR3I	=	DR3 for target at infinity*
DR39	=	DR1P + DR2 + DR3
	=	Total ("true") range delay for target height at 39 km
DRI	=	Total ("true") range delay for target at infinity
ERROR	=	DR1P - DR1S
	=	Range estimate error.

All angles are expressed in milliradians.
All distances are expressed in meters.

In five of the 96 profiles, ducting occurred at $\beta_o = 0$ mr. and was indicated by the word "DUCTING".

* DR3I is computed from eq. (A-11) by setting $\alpha = 0$. This assumes that the ray path above 39 km is a straight line and that the signal velocity is that of free space. This assumption is quite good for S-band and above when ionospheric effects are negligible.

1JAN1263 NØ=320.80 GMR= 8.33 DN= 47.69 DNP= 56.54 N9P=105.27

BØ	GM	DRIP	DRIS	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.71	80.11	79.76	30.06	-1.40	1.50	108.77	111.67	0.36
10	10.54	63.38	62.99	21.53	-4.44	-1.51	80.48	83.41	0.40
20	8.33	51.77	51.35	17.02	-4.96	-2.33	63.82	66.45	0.42
30	6.87	43.30	42.89	14.03	-4.85	-2.54	52.48	54.79	0.41
40	5.82	36.91	36.53	11.89	-4.54	-2.52	44.26	46.29	0.38
50	5.04	31.97	31.62	10.28	-4.19	-2.40	38.06	39.85	0.35

2JAN0058 NØ=311.30 GMR= 8.10 DN= 50.38 DNP= 50.80 N9P=104.59

BØ	GM	DRIP	DRIS	DR2	DR3	DR3I	DR39	DRI	ERROR
0	13.17	78.23	77.72	26.11	-1.74	1.02	102.60	105.36	0.51
10	10.22	61.96	61.50	20.26	-4.20	-1.44	78.02	80.78	0.45
20	8.10	50.70	50.26	16.05	-4.69	-2.22	62.06	64.53	0.44
30	6.67	42.49	42.05	13.22	-4.57	-2.40	51.13	53.30	0.44
40	5.65	36.29	35.86	11.19	-4.27	-2.37	43.20	45.11	0.43
50	4.88	31.48	31.06	9.67	-3.94	-2.26	37.21	38.89	0.41

2JAN1255 NØ=306.80 GMR= 7.86 DN= 45.51 DNP= 48.25 N9P=103.93

BØ	GM	DRIP	DRIS	DR2	DR3	DR3I	DR39	DRI	ERROR
0	11.82	77.96	77.76	23.10	-2.02	0.69	99.05	101.76	0.20
10	9.74	61.76	61.67	19.04	-3.98	-1.30	76.81	79.49	0.08
20	7.86	50.48	50.42	15.36	-4.48	-2.07	61.36	63.77	0.06
30	6.52	42.26	42.20	12.73	-4.40	-2.28	50.60	52.72	0.06
40	5.54	36.07	35.99	10.81	-4.12	-2.26	42.76	44.62	0.07
50	4.79	31.27	31.18	9.36	-3.81	-2.17	36.82	38.46	0.08

3JAN0063 NØ=305.20 GMR= 7.79 DN= 44.19 DNP= 47.72 N9P=103.88

BØ	GM	DRIP	DRIS	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.83	78.11	77.71	30.78	-0.56	2.00	108.33	110.88	0.40
10	9.98	62.26	61.66	19.41	-4.03	-1.38	77.64	80.29	0.60
20	7.79	51.10	50.43	15.14	-4.42	-2.03	61.82	64.21	0.66
30	6.43	42.85	42.21	12.50	-4.31	-2.20	51.04	53.15	0.64
40	5.47	36.59	36.00	10.63	-4.04	-2.19	43.17	45.03	0.58
50	4.74	31.72	31.19	9.21	-3.74	-2.10	37.20	38.84	0.53

3JAN1263 N0=294.10 GMR= 7.08 DN= 24.97 DNP= 26.08 N9P=103.82

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	9.14	78.98	78.87	17.12	-2.25	0.26	93.85	96.36	0.11
10	8.33	63.02	63.01	15.60	-3.39	-0.93	75.23	77.69	0.00
20	7.08	51.58	51.60	13.26	-3.85	-1.60	60.99	63.23	-0.03
30	6.01	43.19	43.20	11.26	-3.85	-1.85	50.60	52.59	-0.01
40	5.17	36.85	36.84	9.68	-3.66	-1.90	42.87	44.64	0.00
50	4.51	31.94	31.92	8.44	-3.41	-1.85	36.98	38.54	0.03

4JAN0057 N0=303.80 GMR= 7.70 DN= 42.02 DNP= 37.45 N9P=104.46

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	12.24	77.96	77.82	23.68	-1.85	0.80	99.79	102.44	0.14
10	9.54	61.91	61.80	18.46	-3.88	-1.25	76.49	79.11	0.11
20	7.70	50.65	50.55	14.90	-4.34	-1.98	61.20	63.57	0.09
30	6.41	42.41	42.32	12.39	-4.27	-2.18	50.54	52.62	0.09
40	5.46	36.20	36.09	10.55	-4.02	-2.18	42.73	44.56	0.10
50	4.73	31.38	31.27	9.14	-3.71	-2.09	36.81	38.43	0.11

4JAN1249 N0=303.80 GMR= 7.71 DN= 42.22 DNP= 39.36 N9P=103.17

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	12.12	78.08	77.79	23.45	-1.88	0.77	99.65	102.30	0.29
10	9.58	62.04	61.78	18.53	-3.89	-1.26	76.68	79.31	0.26
20	7.71	50.79	50.53	14.91	-4.35	-1.98	61.36	63.72	0.26
30	6.40	42.56	42.30	12.39	-4.27	-2.18	50.68	52.77	0.26
40	5.45	36.33	36.08	10.54	-4.01	-2.18	42.86	44.70	0.26
50	4.73	31.51	31.26	9.14	-3.71	-2.09	36.93	38.56	0.25

5JAN0048 N0=297.10 GMR= 7.32 DN= 32.76 DNP= 27.00 N9P=105.16

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	11.53	78.56	78.16	21.81	-1.89	0.65	98.48	101.02	0.40
10	8.93	62.71	62.30	16.90	-3.60	-1.09	76.01	78.52	0.41
20	7.32	51.42	51.01	13.85	-4.03	-1.75	61.24	63.53	0.42
30	6.14	43.12	42.71	11.62	-3.99	-1.96	50.76	52.78	0.41
40	5.26	36.83	36.43	9.95	-3.77	-1.98	43.01	44.79	0.40
50	4.58	31.94	31.56	8.65	-3.50	-1.92	37.10	38.68	0.38

1FEB1263 N0=297.30 GMR= 7.14 DN= 23.40 DNP= 26.45 N9P=104.96

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	8.47	80.06	79.66	16.03	-2.39	0.19	93.71	96.28	0.40
10	8.33	63.85	63.61	15.77	-3.44	-0.92	76.18	78.70	0.24
20	7.14	52.25	52.06	13.53	-3.93	-1.63	61.85	64.15	0.20
30	6.07	43.76	43.55	11.49	-3.93	-1.89	51.33	53.37	0.21
40	5.22	37.34	37.12	9.89	-3.73	-1.93	43.49	45.30	0.22
50	4.56	32.37	32.15	8.62	-3.48	-1.88	37.51	39.11	0.22

2FEB1263 N0=329.30 GMR= 9.06 DN= 69.86 DNP= 59.23 N9P=105.32

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	18.02	77.58	77.39	37.79	0.08	2.98	115.46	118.35	0.19
10	12.04	60.99	60.73	25.26	-5.05	-1.96	81.20	84.29	0.25
20	9.06	49.79	49.52	19.00	-5.59	-2.86	63.20	65.93	0.27
30	7.31	41.67	41.40	15.33	-5.36	-2.99	51.64	54.01	0.26
40	6.13	35.55	35.29	12.84	-4.95	-2.89	43.44	45.50	0.25
50	5.26	30.81	30.57	11.02	-4.53	-2.71	37.31	39.12	0.24

3FEB0062 N0=323.10 GMR= 8.13 DN= 34.61 DNP= 37.35 N9P=104.85

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.46	82.41	82.25	31.81	-1.14	1.77	113.08	116.00	0.16
10	10.15	65.44	65.08	20.88	-4.36	-1.38	81.96	84.94	0.36
20	8.13	53.41	52.99	16.74	-4.86	-2.17	65.29	67.98	0.42
30	6.79	44.59	44.20	13.98	-4.80	-2.43	53.77	56.14	0.40
40	5.80	37.96	37.60	11.93	-4.54	-2.45	45.36	47.44	0.36
50	5.04	32.85	32.52	10.35	-4.20	-2.36	39.00	40.84	0.33

3FEB1257 N0=315.60 GMR= 8.00 DN= 39.00 DNP= 35.67 N9P=101.60

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	11.83	80.07	80.31	23.78	-2.20	0.68	101.65	104.53	-0.24
10	9.74	63.28	63.61	19.58	-4.12	-1.28	78.74	81.58	-0.33
20	8.00	51.53	51.89	16.07	-4.68	-2.11	62.92	65.48	-0.36
30	6.68	43.00	43.34	13.43	-4.63	-2.38	51.80	54.05	-0.34
40	5.70	36.61	36.91	11.44	-4.36	-2.39	43.69	45.66	-0.31
50	4.94	31.68	31.95	9.92	-4.04	-2.30	37.56	39.30	-0.27

4FEB0048 N0=294.50 GMR= 7.17 DN= 28.91 DNP= 26.70 N9P= 98.44

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	10.73	77.96	78.32	20.12	-2.01	0.50	96.07	98.58	-0.36
10	8.62	62.14	62.52	16.17	-3.48	-1.01	74.84	77.31	-0.37
20	7.17	50.82	51.21	13.44	-3.91	-1.66	60.36	62.60	-0.39
30	6.06	42.50	42.88	11.36	-3.89	-1.90	49.97	51.96	-0.38
40	5.20	36.22	36.57	9.75	-3.69	-1.94	42.28	44.04	-0.35
50	4.53	31.36	31.69	8.50	-3.44	-1.88	36.42	37.98	-0.33

4FEB1249 N0=310.00 GMR= 7.96 DN= 45.35 DNP= 44.60 N9P=105.64

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	12.93	78.53	78.33	25.53	-1.79	0.96	102.28	105.03	0.20
10	9.96	62.25	62.06	19.68	-4.10	-1.36	77.83	80.56	0.19
20	7.96	50.90	50.71	15.71	-4.58	-2.12	62.02	64.48	0.19
30	6.59	42.60	42.42	13.00	-4.49	-2.32	51.12	53.28	0.18
40	5.60	36.34	36.16	11.04	-4.21	-2.31	43.17	45.07	0.18
50	4.85	31.49	31.32	9.56	-3.89	-2.21	37.16	38.84	0.17

5FEB0059 N0=296.60 GMR= 7.33 DN= 33.85 DNP= 33.23 N9P=106.18

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	11.75	78.24	77.90	22.21	-1.83	0.70	98.62	101.15	0.34
10	8.99	62.46	62.08	16.99	-3.61	-1.11	75.84	78.34	0.38
20	7.33	51.23	50.84	13.84	-4.03	-1.75	61.04	63.31	0.39
30	6.14	42.95	42.57	11.60	-3.98	-1.96	50.57	52.59	0.38
40	5.25	36.68	36.32	9.92	-3.76	-1.98	42.84	44.62	0.36
50	4.57	31.81	31.47	8.63	-3.49	-1.92	36.95	38.52	0.34

5FEB1256 N0=305.50 GMR= 7.62 DN= 35.20 DNP= 27.29 N9P=105.43

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	11.68	79.50	79.21	22.72	-2.03	0.66	100.19	102.88	0.29
10	9.28	63.22	62.96	18.05	-3.83	-1.17	77.44	80.10	0.26
20	7.62	51.70	51.46	14.82	-4.31	-1.90	62.21	64.62	0.24
30	6.38	43.28	43.04	12.41	-4.26	-2.14	51.43	53.56	0.25
40	5.45	36.93	36.68	10.60	-4.03	-2.15	43.51	45.38	0.25
50	4.74	32.01	31.77	9.21	-3.73	-2.08	37.48	39.14	0.24

1MAR1263 N0=328.10 GMR= 8.57 DN= 48.45 DNP= 41.50 N9P=105.40

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	12.58	81.31	80.84	26.30	-2.27	0.83	105.34	108.44	0.48
10	10.65	64.05	63.71	22.25	-4.59	-1.52	81.70	84.78	0.34
20	8.57	52.17	51.86	17.90	-5.22	-2.47	64.85	67.60	0.31
30	7.07	43.59	43.27	14.77	-5.11	-2.70	53.25	55.66	0.31
40	5.99	37.14	36.83	12.51	-4.78	-2.68	44.86	46.97	0.31
50	5.17	32.16	31.86	10.80	-4.41	-2.55	38.56	40.41	0.30

2MAR0063 N0=336.90 GMR= 9.17 DN= 64.10 DNP= 53.73 N9P=106.54

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	17.49	80.03	79.63	37.54	-0.42	2.66	117.14	120.22	0.39
10	11.99	62.88	62.43	25.74	-5.16	-1.92	83.45	86.69	0.44
20	9.17	51.25	50.80	19.67	-5.77	-2.90	65.15	68.02	0.46
30	7.44	42.84	42.39	15.96	-5.56	-3.06	53.23	55.73	0.45
40	6.25	36.51	36.09	13.40	-5.16	-2.98	44.75	46.93	0.43
50	5.37	31.63	31.23	11.52	-4.72	-2.81	38.42	40.33	0.40

2MAR1262 N0=325.40 GMR= 8.35 DN= 41.99 DNP= 38.98 N9P=106.77

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	13.57	81.72	81.45	28.13	-1.92	1.10	107.93	110.95	0.27
10	10.38	64.60	64.31	21.52	-4.47	-1.45	81.65	84.67	0.28
20	8.35	52.65	52.36	17.31	-5.04	-2.32	64.92	67.64	0.29
30	6.94	43.97	43.68	14.37	-4.96	-2.57	53.38	55.77	0.28
40	5.90	37.45	37.17	12.21	-4.66	-2.57	45.00	47.10	0.28
50	5.11	32.42	32.15	10.57	-4.30	-2.46	38.69	40.53	0.27

3MAR0060 N0=344.00 GMR= 9.44 DN= 66.72 DNP= 62.40 N9P=[illegible]

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	17.29	80.76	80.32	37.89	-0.72	2.52	117.93	121.17	0.44
10	12.42	63.30	62.83	27.21	-5.42	-2.04	85.09	88.47	0.47
20	9.44	51.54	51.05	20.69	-6.07	-3.08	66.16	69.15	0.49
30	7.64	43.05	42.57	16.74	-5.84	-3.25	53.94	56.54	0.48
40	6.41	36.67	36.22	14.04	-5.41	-3.15	45.30	47.56	0.45
50	5.51	31.76	31.33	12.05	-4.95	-2.97	38.86	40.84	0.42

3MAR1263 N0=334.80 GMR= 8.74 DN= 47.06 DNP= 45.70 N9P=105.70

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	14.28	82.50	82.16	30.45	-1.89	1.30	111.06	114.25	0.34
10	11.01	65.02	64.65	23.48	-4.82	-1.62	83.68	86.88	0.37
20	8.74	52.93	52.55	18.64	-5.43	-2.56	66.14	69.01	0.38
30	7.22	44.17	43.80	15.39	-5.32	-2.81	54.23	56.75	0.37
40	6.12	37.60	37.24	13.03	-4.99	-2.79	45.65	47.85	0.36
50	5.29	32.54	32.20	11.26	-4.60	-2.67	39.20	41.13	0.34

4MAR0063 N0=342.60 GMR= 8.98 DN= 46.83 DNP= 42.50 N9P=106.03

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	12.02	83.50	83.45	26.24	-2.74	0.67	107.01	110.41	0.05
10	10.92	65.33	65.54	23.82	-4.92	-1.57	84.23	87.59	-0.20
20	8.98	52.90	53.18	19.59	-5.70	-2.69	66.78	69.79	-0.29
30	7.45	44.02	44.27	16.24	-5.63	-3.01	54.63	57.25	-0.25
40	6.31	37.42	37.62	13.75	-5.27	-2.99	45.90	48.18	-0.20
50	5.44	32.35	32.51	11.86	-4.85	-2.86	39.36	41.36	-0.15

4MAR1246 N0=317.00 GMR= 7.85 DN= 29.67 DNP= 27.43 N9P=105.62

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	12.00	82.38	82.02	24.24	-2.18	0.71	104.44	107.33	0.36
10	9.49	65.44	65.06	19.17	-4.07	-1.20	80.53	83.40	0.38
20	7.85	53.41	53.04	15.86	-4.60	-2.00	64.66	67.27	0.38
30	6.61	44.63	44.26	13.34	-4.58	-2.28	53.40	55.69	0.37
40	5.66	38.03	37.66	11.42	-4.33	-2.31	45.11	47.14	0.37
50	4.92	32.94	32.58	9.92	-4.02	-2.24	38.83	40.62	0.36

5MAR0063 N0=353.70 GMR= 9.80 DN= 69.23 DNP= 55.87 N9P=105.96

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	16.17	81.37	81.42	36.43	-1.55	1.95	116.24	119.75	-0.06
10	12.59	63.24	63.50	28.37	-5.64	-2.06	85.96	89.54	-0.26
20	9.80	51.17	51.51	22.08	-6.48	-3.31	66.77	69.93	-0.34
30	7.95	42.59	42.90	17.91	-6.27	-3.55	54.23	56.96	-0.30
40	6.66	36.22	36.47	15.00	-5.81	-3.45	45.42	47.77	-0.25
50	5.71	31.33	31.53	12.85	-5.30	-3.24	38.89	40.95	-0.20

1APR1263 N0=364.70 GMR=10.42 DN= 81.40 DNP= 48.00 N9P=104.84

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	16.08	80.99	80.96	37.36	-1.88	1.87	116.48	120.23	0.03
10	13.35	62.35	62.84	31.01	-6.09	-2.27	87.27	91.09	-0.49
20	10.42	50.26	50.92	24.21	-7.13	-3.79	67.33	70.67	-0.67
30	8.39	41.80	42.40	19.48	-6.87	-4.02	54.41	57.26	-0.60
40	6.98	35.55	36.05	16.20	-6.31	-3.86	45.44	47.90	-0.49
50	5.96	30.76	31.16	13.83	-5.73	-3.59	38.86	41.00	-0.40

2APR0060 N0=350.20 GMR= 9.89 DN= 77.93 DNP= 70.95 N9P=104.80

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	15.93	79.85	79.32	35.54	-1.58	1.87	113.81	117.26	0.53
10	12.94	62.06	61.83	28.86	-5.69	-2.19	85.22	88.73	0.22
20	9.89	50.39	50.24	22.05	-6.50	-3.42	65.94	69.02	0.15
30	7.94	42.07	41.91	17.71	-6.23	-3.58	53.56	56.21	0.17
40	6.62	35.86	35.67	14.76	-5.73	-3.43	44.90	47.19	0.20
50	5.67	31.07	30.86	12.63	-5.21	-3.20	38.49	40.50	0.21

2APR1256 N0=333.90 GMR= 8.38 DN= 30.08 DNP= 14.97 N9P=106.00

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	14.12	84.92	84.73	30.02	-1.93	1.25	113.01	116.19	0.19
10	10.36	67.30	66.90	22.03	-4.60	-1.42	84.73	87.92	0.40
20	8.38	54.80	54.35	17.81	-5.16	-2.28	67.45	70.33	0.45
30	7.03	45.68	45.24	14.94	-5.13	-2.59	55.49	58.03	0.44
40	6.01	38.85	38.43	12.77	-4.85	-2.63	46.76	48.99	0.41
50	5.22	33.60	33.21	11.08	-4.50	-2.54	40.18	42.14	0.39

3APR0063 N0=297.20 GMR= 7.48 DN= 40.64 DNP= 34.75 N9P=105.40

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	12.74	77.31	76.91	24.13	-1.58	0.94	99.85	102.37	0.39
10	9.31	61.63	61.21	17.63	-3.71	-1.20	75.54	78.05	0.42
20	7.48	50.56	50.14	14.16	-4.13	-1.86	60.59	62.86	0.43
30	6.22	42.43	42.00	11.78	-4.05	-2.05	50.15	52.16	0.42
40	5.30	36.26	35.85	10.03	-3.81	-2.04	42.48	44.25	0.41
50	4.60	31.47	31.07	8.70	-3.53	-1.96	36.64	38.21	0.39

3APR1263 N0=316.00 GMR= 8.40 DN= 58.00 DNP= 52.15 N9P=105.63

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.30	77.71	77.23	30.79	-1.05	1.74	107.45	110.23	0.48
10	10.86	61.45	60.95	21.87	-4.47	-1.63	78.85	81.69	0.49
20	8.40	50.29	49.79	16.90	-4.95	-2.42	62.24	64.77	0.50
30	6.86	42.15	41.66	13.79	-4.79	-2.57	51.16	53.37	0.50
40	5.78	36.00	35.52	11.63	-4.46	-2.52	43.17	45.11	0.48
50	4.99	31.23	30.78	10.02	-4.09	-2.38	37.16	38.87	0.45

4APR0051 N0=313.30 GMR= 8.37 DN= 60.62 DNP= 53.40 N9P=105.65

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	44.72	76.67	76.33	89.26	58.99	50.04	224.91	215.96	0.34
10	11.20	61.08	60.25	22.34	-4.53	-1.74	78.90	81.69	0.83
20	8.37	50.16	49.26	16.71	-4.90	-2.42	61.96	64.45	0.90
30	6.80	42.12	41.24	13.56	-4.71	-2.53	50.97	53.14	0.87
40	5.73	36.01	35.19	11.42	-4.37	-2.46	43.05	44.96	0.82
50	4.94	31.26	30.50	9.84	-4.02	-2.33	37.08	38.77	0.76

4APR1263 N0=315.50 GMR= 8.16 DN= 47.15 DNP= 61.37 N9P=105.51

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	19.64	79.76	78.96	39.48	1.59	4.08	120.83	123.31	0.79
10	10.66	63.59	62.45	21.42	-4.39	-1.56	80.62	83.45	1.14
20	8.16	52.22	50.97	16.39	-4.78	-2.24	63.83	66.38	1.25
30	6.70	43.81	42.61	13.46	-4.64	-2.39	52.62	54.87	1.20
40	5.68	37.41	36.31	11.41	-4.35	-2.37	44.47	46.45	1.10
50	4.92	32.44	31.44	9.88	-4.01	-2.27	38.31	40.05	1.00

5APR0063 N0=342.40 GMR= 9.65 DN= 78.36 DNP= 74.78 N9P=105.50

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	DUCTING								
10	14.16	62.19	60.92	30.87	-5.94	-2.59	87.12	90.47	1.27
20	9.65	51.12	49.59	21.05	-6.21	-3.28	65.96	68.90	1.53
30	7.67	42.86	41.41	16.71	-5.85	-3.30	53.72	56.28	1.45
40	6.40	36.59	35.28	13.94	-5.38	-3.15	45.15	47.38	1.31
50	5.49	31.72	30.54	11.95	-4.91	-2.95	38.76	40.71	1.17

1MAY1261 N0=361.40 GMR=10.08 DN= 70.93 DNP= 79.40 N9P=105.93

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	16.13	82.65	82.33	37.13	-1.77	1.91	118.01	121.69	0.33
10	12.91	64.11	64.06	29.72	-5.89	-2.14	87.94	91.69	0.05
20	10.08	51.84	51.89	23.20	-6.81	-3.50	68.24	71.54	-0.04
30	8.17	43.16	43.17	18.79	-6.59	-3.75	55.37	58.21	-0.01
40	6.83	36.72	36.68	15.71	-6.09	-3.63	46.34	48.80	0.04
50	5.85	31.78	31.70	13.45	-5.55	-3.41	39.68	41.82	0.08

2MAY0061 N0=347.30 GMR= 9.32 DN= 56.47 DNP= 44.03 N9P=105.58

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.90	82.84	82.60	32.96	-1.95	1.48	113.85	117.28	0.24
10	11.70	64.77	64.68	25.89	-5.25	-1.80	85.41	88.86	0.09
20	9.32	52.50	52.47	20.62	-6.02	-2.95	67.10	70.18	0.03
30	7.65	43.74	43.68	16.92	-5.89	-3.22	54.78	57.45	0.06
40	6.45	37.22	37.13	14.26	-5.49	-3.17	45.99	48.31	0.09
50	5.55	32.22	32.09	12.26	-5.03	-3.00	39.45	41.48	0.13

2MAY1263 N0=355.40 GMR= 9.75 DN= 64.49 DNP= 53.95 N9P=105.65

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.69	82.71	82.51	33.27	-2.23	1.38	113.75	117.36	0.20
10	12.28	64.28	64.38	27.80	-5.58	-1.96	86.50	90.12	-0.09
20	9.75	51.98	52.17	22.07	-6.46	-3.26	67.59	70.79	-0.20
30	7.95	43.26	43.42	17.99	-6.29	-3.52	54.97	57.73	-0.16
40	6.67	36.80	36.89	15.09	-5.83	-3.44	46.06	48.45	-0.09
50	5.73	31.84	31.88	12.95	-5.33	-3.24	39.45	41.55	-0.05

3MAY0063 N0=377.70 GMR=11.09 DN= 92.10 DNP= 76.00 N9P=105.68

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	30.70	81.18	80.94	73.87	14.09	15.71	169.13	170.76	0.24
10	15.09	62.77	62.53	36.31	-6.88	-2.77	92.19	96.30	0.24
20	11.09	50.80	50.61	26.68	-7.89	-4.32	69.59	73.16	0.19
30	8.80	42.33	42.12	21.15	-7.49	-4.45	55.99	59.03	0.21
40	7.28	36.02	35.79	17.51	-6.84	-4.22	46.69	49.31	0.23
50	6.20	31.18	30.93	14.91	-6.19	-3.92	39.89	42.17	0.25

3MAY1263 N0=356.20 GMR= 9.55 DN= 53.92 DNP= 58.64 N9P=104.86

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.54	85.16	84.43	35.26	-1.90	1.69	118.52	122.11	0.73
10	12.15	66.70	65.98	27.56	-5.55	-1.92	88.72	92.35	0.72
20	9.55	54.16	53.42	21.66	-6.31	-3.07	69.50	72.75	0.74
30	7.82	45.13	44.41	17.74	-6.16	-3.34	56.71	59.53	0.72
40	6.60	38.39	37.70	14.95	-5.74	-3.29	47.60	50.05	0.69
50	5.68	33.21	32.56	12.87	-5.27	-3.12	40.81	42.96	0.65

4MAY0063 N0=333.40 GMR= 8.32 DN= 27.98 DNP= 26.90 N9P=104.78

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	12.94	85.30	84.97	27.48	-2.29	0.91	110.49	113.69	0.32
10	10.06	67.51	67.13	21.37	-4.51	-1.33	84.37	87.55	0.38
20	8.32	54.93	54.54	17.66	-5.12	-2.24	67.47	70.36	0.39
30	7.00	45.78	45.39	14.86	-5.10	-2.56	55.54	58.08	0.39
40	5.99	38.93	38.56	12.71	-4.83	-2.60	46.81	49.04	0.37
50	5.20	33.67	33.32	11.04	-4.48	-2.52	40.22	42.18	0.35

4MAY1259 N0=334.20 GMR= 9.10 DN= 64.81 DNP= 50.95 N9P=106.00

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	16.05	79.40	79.07	34.18	-1.12	1.98	112.46	115.56	0.33
10	11.72	62.25	62.03	24.94	-5.03	-1.84	82.16	85.34	0.22
20	9.10	50.67	50.50	19.37	-5.68	-2.86	64.36	67.18	0.17
30	7.40	42.35	42.16	15.74	-5.49	-3.04	52.60	55.05	0.19
40	6.21	36.11	35.91	13.21	-5.09	-2.96	44.23	46.37	0.20
50	5.34	31.29	31.08	11.35	-4.66	-2.79	37.98	39.86	0.21

5MAY0055 N0=313.40 GMR= 8.01 DN= 42.89 DNP= 33.14 N9P=105.58

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	13.16	79.55	79.31	26.28	-1.79	1.02	104.04	106.85	0.25
10	9.94	63.05	62.81	19.85	-4.15	-1.35	78.75	81.55	0.24
20	8.01	51.50	51.27	15.98	-4.66	-2.14	62.83	65.35	0.23
30	6.65	43.09	42.86	13.28	-4.58	-2.36	51.79	54.00	0.23
40	5.66	36.75	36.52	11.28	-4.30	-2.36	43.74	45.68	0.24
50	4.90	31.85	31.62	9.77	-3.97	-2.26	37.65	39.37	0.24

1JUN1260 N0=365.40 GMR= 9.99 DN= 60.91 DNP= 48.20 N9P=105.15

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.97	84.92	84.68	34.85	-2.37	1.44	117.41	121.22	0.24
10	12.49	65.91	65.94	29.06	-5.83	-2.00	89.15	92.98	-0.03
20	9.99	53.19	53.31	23.24	-6.78	-3.39	69.65	73.05	-0.12
30	8.17	44.20	44.29	19.00	-6.63	-3.70	56.57	59.51	-0.08
40	6.86	37.55	37.58	15.96	-6.16	-3.63	47.35	49.89	-0.03
50	5.89	32.46	32.45	13.70	-5.64	-3.42	40.52	42.74	0.01

2JUN0057 N0=366.90 GMR=10.03 DN= 60.72 DNP= 53.70 N9P=105.15

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	16.27	85.07	84.94	38.02	-1.85	1.94	121.25	125.04	0.14
10	12.65	66.09	66.12	29.56	-5.90	-2.04	89.74	93.60	-0.03
20	10.03	53.34	53.44	23.44	-6.84	-3.41	69.94	73.37	-0.09
30	8.20	44.31	44.38	19.16	-6.68	-3.72	56.79	59.75	-0.06
40	6.89	37.63	37.66	16.09	-6.21	-3.65	47.51	50.07	-0.02
50	5.92	32.53	32.51	13.81	-5.69	-3.45	40.65	42.89	0.01

2JUN1262 N0=374.80 GMR=10.43 DN= 67.52 DNP= 62.70 N9P=105.99

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	17.16	85.20	84.97	40.97	-1.61	2.32	124.57	128.49	0.23
10	13.29	65.95	65.93	31.72	-6.26	-2.22	91.41	95.45	0.02
20	10.43	53.17	53.23	24.90	-7.28	-3.71	70.79	74.36	-0.06
30	8.47	44.16	44.19	20.22	-7.08	-4.01	57.30	60.37	-0.03
40	7.09	37.50	37.49	16.92	-6.56	-3.91	47.87	50.52	0.01
50	6.08	32.41	32.36	14.50	-5.98	-3.68	40.92	43.23	0.05

3JUN0037 N0=375.80 GMR=10.39 DN= 64.16 DNP= 57.45 N9P=106.03

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	16.72	86.10	85.70	40.02	-1.86	2.11	124.25	128.22	0.40
10	13.20	66.74	66.52	31.60	-6.25	-2.19	92.09	96.14	0.22
20	10.39	53.84	53.68	24.86	-7.26	-3.66	71.44	75.04	0.16
30	8.46	44.72	44.54	20.24	-7.07	-3.97	57.88	60.98	0.18
40	7.09	37.98	37.77	16.96	-6.56	-3.88	48.38	51.05	0.20
50	6.08	32.82	32.60	14.54	-5.99	-3.66	41.36	43.70	0.22

3JUN1247 N0=381.50 GMR=10.53 DN= 62.30 DNP= 60.43 N9P=106.00

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	17.82	87.36	86.87	43.30	-1.43	2.61	129.23	133.27	0.49
10	13.52	67.80	67.35	32.85	-6.46	-2.28	94.19	98.38	0.45
20	10.53	54.73	54.28	25.58	-7.46	-3.75	72.85	76.56	0.45
30	8.57	45.44	45.00	20.81	-7.26	-4.06	58.99	62.19	0.44
40	7.19	38.57	38.13	17.45	-6.74	-3.98	49.27	52.04	0.43
50	6.17	33.31	32.89	14.97	-6.17	-3.75	42.11	44.53	0.42

4JUN0063 N0=367.10 GMR= 9.85 DN= 51.75 DNP= 43.04 N9P=104.40

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.87	86.49	86.47	37.11	-2.04	1.78	121.56	125.37	0.02
10	12.29	67.36	67.42	28.73	-5.79	-1.93	90.30	94.17	-0.06
20	9.85	54.36	54.45	23.02	-6.70	-3.25	70.68	74.13	-0.09
30	8.11	45.11	45.19	18.96	-6.59	-3.60	57.48	60.48	-0.07
40	6.84	38.28	38.32	15.99	-6.16	-3.57	48.11	50.71	-0.04
50	5.89	33.06	33.07	13.76	-5.65	-3.39	41.17	43.43	-0.00

4JUN1263 N0=361.50 GMR=10.40 DN= 84.95 DNP= 64.13 N9P=104.97

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	17.12	79.93	79.81	39.43	-1.27	2.36	118.09	121.72	0.13
10	13.63	61.67	61.97	31.38	-6.12	-2.37	86.93	90.68	-0.30
20	10.40	49.85	50.28	23.95	-7.07	-3.80	66.73	70.00	-0.43
30	8.33	41.52	41.90	19.17	-6.77	-3.97	53.92	56.72	-0.38
40	6.92	35.34	35.64	15.92	-6.21	-3.80	45.06	47.47	-0.30
50	5.91	30.60	30.83	13.58	-5.63	-3.53	38.55	40.65	-0.23

5JUN0060 N0=329.60 GMR= 8.66 DN= 50.67 DNP= 45.66 N9P=105.03

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	18.10	80.85	80.72	38.00	0.13	3.03	118.98	121.88	0.14
10	11.05	63.84	63.56	23.20	-4.74	-1.65	82.30	85.40	0.28
20	8.66	52.03	51.73	18.17	-5.30	-2.53	64.90	67.68	0.30
30	7.13	43.46	43.16	14.96	-5.18	-2.75	53.24	55.66	0.30
40	6.03	37.03	36.74	12.65	-4.84	-2.72	44.83	46.95	0.29
50	5.21	32.06	31.78	10.92	-4.46	-2.60	38.52	40.39	0.28

1JUL1258 N0=353.80 GMR= 9.76 DN= 67.03 DNP= 53.70 N9P=107.17

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	18.85	82.30	81.82	42.48	-0.00	3.33	124.76	128.11	0.47
10	12.78	64.36	63.84	28.79	-5.71	-2.12	87.45	91.03	0.52
20	9.76	52.30	51.77	21.98	-6.44	-3.27	67.84	71.01	0.53
30	7.90	43.63	43.10	17.83	-6.22	-3.47	55.21	57.95	0.53
40	6.62	37.15	36.64	14.91	-5.76	-3.37	46.30	48.69	0.51
50	5.68	32.16	31.67	12.79	-5.26	-3.18	39.69	41.77	0.49

2JUL0059 N0=350.50 GMR= 9.38 DN= 54.50 DNP= 41.98 N9P=106.13

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	15.35	83.87	83.44	34.27	-1.84	1.63	116.29	119.77	0.43
10	11.74	65.61	65.30	26.22	-5.32	-1.80	86.51	90.02	0.31
20	9.38	53.19	52.93	20.94	-6.11	-2.97	68.02	71.16	0.26
30	7.71	44.32	44.04	17.20	-5.98	-3.26	55.54	58.26	0.28
40	6.50	37.71	37.41	14.50	-5.58	-3.21	46.64	49.00	0.30
50	5.60	32.64	32.33	12.48	-5.12	-3.04	40.00	42.07	0.31

2JUL1263 N0=371.90 GMR=10.50 DN= 74.77 DNP= 52.68 N9P=106.50

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	14.79	83.66	83.26	35.03	-2.60	1.36	116.09	120.05	0.40
10	13.33	64.50	64.57	31.58	-6.22	-2.25	89.87	93.84	-0.07
20	10.50	51.99	52.21	24.87	-7.30	-3.80	69.56	73.06	-0.22
30	8.49	43.23	43.39	20.10	-7.07	-4.07	56.26	59.26	-0.16
40	7.08	36.75	36.84	16.77	-6.52	-3.94	47.00	49.58	-0.08
50	6.06	31.79	31.82	14.33	-5.93	-3.68	40.19	42.44	-0.03

3JUL0056 N0=361.40 GMR= 9.91 DN= 63.23 DNP= 45.05 N9P=105.37

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	15.52	83.81	83.66	35.72	-2.04	1.66	117.49	121.19	0.14
10	12.50	65.11	65.19	28.77	-5.76	-2.01	88.13	91.87	-0.08
20	9.91	52.59	52.76	22.81	-6.67	-3.35	68.73	72.05	-0.17
30	8.09	43.73	43.86	18.62	-6.51	-3.64	55.85	58.71	-0.13
40	6.79	37.18	37.25	15.63	-6.04	-3.56	46.76	49.24	-0.07
50	5.83	32.15	32.17	13.40	-5.52	-3.36	40.04	42.20	-0.02

3JUL1263 N0=394.50 GMR=11.87 DN=101.57 DNP= 70.50 N9P=105.96

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	41.72	81.86	81.58	104.85	42.88	38.95	229.59	225.66	0.28
10	16.41	63.00	62.69	41.24	-7.61	-3.11	96.64	101.13	0.31
20	11.87	50.90	50.65	29.82	-8.83	-4.94	71.89	75.77	0.25
30	9.34	42.37	42.10	23.46	-8.34	-5.05	57.49	60.78	0.27
40	7.70	36.05	35.75	19.32	-7.58	-4.77	47.79	50.61	0.30
50	6.54	31.19	30.88	16.41	-6.84	-4.40	40.76	43.20	0.31

4JUL0063 N0=379.50 GMR=10.98 DN= 85.21 DNP= 56.28 N9P=107.32

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	21.87	82.93	82.51	52.87	1.67	5.29	137.47	141.09	0.42
10	14.40	63.89	63.77	34.81	-6.70	-2.56	92.00	96.14	0.12
20	10.98	51.54	51.54	26.55	-7.82	-4.20	70.27	73.89	-0.00
30	8.79	42.88	42.84	21.24	-7.50	-4.41	56.62	59.71	0.04
40	7.30	36.48	36.38	17.62	-6.87	-4.22	47.23	49.89	0.11
50	6.22	31.57	31.42	15.02	-6.23	-3.92	40.36	42.67	0.15

4JUL1263 N0=412.30 GMR=12.26 DN= 93.69 DNP= 81.10 N9P=106.79

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	26.13	85.82	85.66	68.63	5.35	9.11	159.81	163.56	0.16
10	16.50	65.57	65.58	43.32	-8.01	-3.09	100.89	105.81	-0.01
20	12.26	52.63	52.71	32.18	-9.46	-5.18	75.35	79.64	-0.08
30	9.73	43.60	43.66	25.55	-9.06	-5.43	60.10	63.73	-0.05
40	8.05	36.98	36.98	21.12	-8.28	-5.18	49.82	52.92	-0.00
50	6.84	31.93	31.89	17.95	-7.48	-4.81	42.40	45.07	0.04

5JUL0054 N0=425.40 GMR=13.59 DN=128.37 DNP=118.60 N9P=104.92

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	DUCTING								
10	21.16	61.64	61.13	57.33	-9.35	-4.06	109.62	114.92	0.51
20	13.59	50.03	49.39	36.81	-10.98	-6.48	75.86	80.36	0.65
30	10.42	41.65	41.05	28.23	-10.15	-6.39	59.74	63.49	0.61
40	8.50	35.42	34.85	23.01	-9.11	-5.93	49.31	52.50	0.57
50	7.17	30.63	30.10	19.41	-8.16	-5.41	41.88	44.63	0.53

1AUG1263 N0=380.80 GMR=10.63 DN= 67.74 DNP= 74.08 N9P=104.73

B0	GM	DRIP	DRIS	DR2	DR3	DR31	DR39	DRI	ERROR
0	16.24	86.40	85.83	39.40	-2.23	1.88	123.58	127.68	0.57
10	13.61	66.84	66.49	33.02	-6.48	-2.31	93.38	97.55	0.35
20	10.63	53.92	53.62	25.77	-7.53	-3.84	72.16	75.85	0.30
30	8.62	44.79	44.48	20.89	-7.31	-4.14	58.37	61.54	0.31
40	7.21	38.03	37.71	17.48	-6.77	-4.03	48.74	51.47	0.32
50	6.18	32.86	32.54	14.97	-6.18	-3.79	41.65	44.03	0.32

2AUG0058 N0=376.70 GMR=10.66 DN= 75.23 DNP= 73.83 N9P=104.47

B0	GM	DRIP	DRIS	DR2	DR3	DR31	DR39	DRI	ERROR
0	20.72	84.44	83.90	49.71	0.74	4.43	134.89	138.58	0.54
10	14.12	65.54	64.99	33.89	-6.56	-2.48	92.87	96.94	0.55
20	10.66	53.05	52.49	25.58	-7.50	-3.91	71.13	74.71	0.56
30	8.57	44.15	43.60	20.56	-7.22	-4.13	57.50	60.58	0.55
40	7.15	37.53	37.00	17.15	-6.65	-3.99	48.03	50.70	0.54
50	6.12	32.46	31.95	14.67	-6.06	-3.74	41.07	43.39	0.51

2AUG1263 N0=380.20 GMR=10.57 DN= 66.17 DNP= 56.57 N9P=104.52

B0	GM	DRIP	DRIS	DR2	DR3	DR31	DR39	DRI	ERROR
0	15.57	86.57	86.01	37.72	-2.51	1.61	121.77	125.89	0.55
10	13.35	66.91	66.66	32.34	-6.38	-2.23	92.86	97.02	0.25
20	10.57	53.92	53.76	25.60	-7.48	-3.80	72.04	75.72	0.16
30	8.60	44.77	44.59	20.81	-7.28	-4.12	58.30	61.46	0.18
40	7.20	38.02	37.80	17.42	-6.75	-4.02	48.69	51.42	0.22
50	6.17	32.86	32.61	14.92	-6.16	-3.78	41.62	44.00	0.24

3AUG0063 N0=371.90 GMR=10.08 DN= 55.79 DNP= 46.57 N9P=105.65

B0	GM	DRIP	DRIS	DR2	DR3	DR31	DR39	DRI	ERROR
0	14.92	86.98	86.53	35.34	-2.56	1.40	119.77	123.72	0.45
10	12.59	67.59	67.33	29.82	-5.98	-2.01	91.44	95.41	0.26
20	10.08	54.55	54.35	23.88	-6.95	-3.42	71.48	75.01	0.20
30	8.27	45.31	45.08	19.59	-6.82	-3.76	58.08	61.13	0.22
40	6.96	38.47	38.22	16.48	-6.35	-3.71	48.60	51.25	0.25
50	5.98	33.25	32.98	14.16	-5.82	-3.51	41.58	43.89	0.27

3AUG1259 N0=381.00 GMR=10.53 DN= 63.23 DNP= 51.80 N9P=104.43

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	22.66	87.02	86.64	55.01	2.39	5.94	144.41	147.97	0.38
10	13.58	67.63	67.17	32.96	-6.47	-2.30	94.12	98.29	0.46
20	10.53	54.61	54.15	25.56	-7.46	-3.76	72.71	76.41	0.46
30	8.57	45.35	44.89	20.78	-7.26	-4.06	58.88	62.07	0.46
40	7.18	38.50	38.04	17.42	-6.73	-3.98	49.19	51.95	0.46
50	6.16	33.26	32.82	14.94	-6.16	-3.75	42.05	44.45	0.44

4AUG0063 N0=373.40 GMR=10.48 DN= 71.98 DNP= 52.40 N9P=104.84

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	17.58	84.43	83.98	41.81	-1.34	2.53	124.91	128.77	0.45
10	13.45	65.34	65.14	31.98	-6.28	-2.28	91.04	95.04	0.20
20	10.48	52.75	52.63	24.93	-7.30	-3.77	70.37	73.90	0.11
30	8.48	43.86	43.72	20.17	-7.07	-4.04	56.96	59.99	0.15
40	7.09	37.29	37.10	16.84	-6.53	-3.92	47.60	50.22	0.19
50	6.07	32.25	32.04	14.41	-5.95	-3.67	40.71	42.99	0.21

4AUG1260 N0=380.30 GMR=10.77 DN= 74.85 DNP= 65.33 N9P=105.10

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	14.98	85.27	84.51	36.29	-2.75	1.40	118.81	122.96	0.76
10	13.81	65.75	65.40	33.44	-6.53	-2.37	92.66	96.82	0.35
20	10.77	53.03	52.78	26.09	-7.64	-3.99	71.47	75.13	0.25
30	8.69	44.09	43.82	21.03	-7.39	-4.25	57.74	60.88	0.27
40	7.24	37.47	37.17	17.54	-6.81	-4.11	48.20	50.90	0.30
50	6.19	32.41	32.09	14.99	-6.20	-3.84	41.20	43.55	0.32

5AUG0063 N0=373.70 GMR=10.42 DN= 68.86 DNP= 54.20 N9P=106.19

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	21.68	84.85	84.57	51.60	1.67	5.18	138.12	141.63	0.28
10	13.53	65.91	65.63	32.20	-6.31	-2.30	91.80	95.81	0.29
20	10.42	53.27	53.01	24.81	-7.26	-3.72	70.82	74.36	0.26
30	8.45	44.29	44.02	20.10	-7.04	-3.98	57.35	60.40	0.27
40	7.07	37.64	37.34	16.81	-6.51	-3.88	47.94	50.57	0.29
50	6.06	32.54	32.24	14.40	-5.94	-3.64	41.00	43.30	0.30

1SEP1254 N0=370.60 GMR=11.19 DN=105.27 DNP=100.30 N9P=105.85

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	DUCTING								
10	16.62	60.71	59.73	39.22	-7.19	-3.23	92.75	96.71	0.98
20	11.19	49.66	48.54	26.41	-7.88	-4.48	68.19	71.59	1.12
30	8.71	41.59	40.52	20.55	-7.31	-4.41	54.84	57.73	1.08
40	7.17	35.51	34.50	16.91	-6.62	-4.12	45.80	48.29	1.01
50	6.09	30.79	29.86	14.36	-5.97	-3.79	39.18	41.36	0.93

2SEP0044 N0=354.80 GMR=10.16 DN= 83.48 DNP= 70.16 N9P=105.28

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	29.68	79.56	79.03	67.08	13.08	14.47	159.72	161.11	0.53
10	13.90	62.19	61.49	31.41	-6.08	-2.47	87.52	91.12	0.70
20	10.16	50.68	49.95	22.96	-6.78	-3.63	66.85	70.01	0.73
30	8.09	42.38	41.66	18.28	-6.43	-3.72	54.22	56.94	0.72
40	6.73	36.15	35.46	15.19	-5.90	-3.55	45.44	47.79	0.69
50	5.75	31.33	30.68	12.98	-5.36	-3.31	38.95	41.01	0.65

2SEP1260 N0=371.80 GMR=10.84 DN= 89.60 DNP= 74.60 N9P=106.21

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	DUCTING								
10	15.36	62.89	62.32	36.37	-6.85	-2.87	92.42	96.40	0.58
20	10.84	51.16	50.48	25.67	-7.59	-4.13	69.25	72.70	0.68
30	8.59	42.69	42.03	20.33	-7.18	-4.21	55.84	58.80	0.66
40	7.12	36.36	35.73	16.85	-6.57	-4.01	46.64	49.20	0.62
50	6.07	31.48	30.89	14.37	-5.95	-3.73	39.89	42.12	0.59

3SEP0055 N0=344.40 GMR= 9.25 DN= 57.22 DNP= 56.70 N9P=105.36

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	17.27	82.36	82.01	37.88	-0.74	2.51	119.49	122.74	0.34
10	11.77	64.58	64.25	25.83	-5.22	-1.83	85.19	88.58	0.33
20	9.25	52.47	52.16	20.29	-5.93	-2.91	66.83	69.65	0.31
30	7.57	43.77	43.45	16.61	-5.78	-3.15	54.60	57.23	0.32
40	6.38	37.27	36.94	13.99	-5.38	-3.10	45.88	48.16	0.33
50	5.49	32.27	31.94	12.04	-4.94	-2.93	39.37	41.37	0.33

3SEP1263 N0=377.40 GMR=10.67 DN= 74.65 DNP= 68.72 N9P=105.90

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.47	84.59	84.11	34.78	-2.86	1.23	116.51	120.61	0.48
10	13.63	65.18	65.14	32.76	-6.42	-2.32	91.52	95.61	0.03
20	10.67	52.52	52.61	25.65	-7.52	-3.92	70.65	74.26	-0.08
30	8.62	43.64	43.69	20.72	-7.28	-4.19	57.08	60.17	-0.05
40	7.19	37.08	37.07	17.28	-6.71	-4.05	47.65	50.31	0.01
50	6.15	32.06	32.01	14.77	-6.11	-3.80	40.72	43.04	0.06

4SEP0063 N0=381.30 GMR=11.28 DN= 95.24 DNP= 88.90 N9P=105.46

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	DUCTING								
10	15.32	62.41	62.40	37.20	-7.02	-2.83	92.59	96.78	0.01
20	11.28	50.42	50.50	27.40	-8.11	-4.47	69.71	73.34	-0.08
30	8.94	41.97	42.02	21.70	-7.70	-4.61	55.97	59.06	-0.04
40	7.39	35.71	35.70	17.93	-7.02	-4.38	46.63	49.27	0.01
50	6.29	30.91	30.86	15.25	-6.35	-4.05	39.82	42.12	0.06

4SEP1257 N0=370.00 GMR= 9.79 DN= 44.62 DNP= 43.59 N9P=106.56

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	10.37	88.52	88.08	24.43	-3.67	0.33	109.28	113.28	0.45
10	11.64	68.72	68.71	27.44	-5.65	-1.71	90.51	94.44	0.01
20	9.79	55.32	55.44	23.07	-6.69	-3.17	71.69	75.21	-0.13
30	8.13	45.88	45.97	19.16	-6.64	-3.59	58.40	61.45	-0.08
40	6.88	38.93	38.95	16.20	-6.23	-3.58	48.90	51.55	-0.02
50	5.93	33.62	33.59	13.95	-5.72	-3.41	41.65	44.16	0.03

5SEP0063 N0=371.10 GMR=10.37 DN= 70.21 DNP= 69.35 N9P=105.30

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	16.65	84.62	83.94	39.36	-1.77	2.09	122.21	126.08	0.68
10	13.38	65.64	65.16	31.62	-6.22	-2.26	91.05	95.00	0.48
20	10.37	53.10	52.67	24.51	-7.18	-3.69	70.43	73.92	0.43
30	8.39	44.20	43.76	19.82	-6.94	-3.94	57.08	60.08	0.44
40	7.01	37.59	37.14	16.57	-6.42	-3.82	47.74	50.34	0.45
50	6.01	32.52	32.07	14.19	-5.85	-3.58	40.85	43.12	0.44

1OCT1256 N0=330.50 GMR= 8.88 DN= 59.74 DNP= 44.10 N9P=104.48

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	12.26	79.81	79.34	25.81	-2.41	0.74	103.21	106.37	0.47
10	11.29	62.64	62.36	23.77	-4.83	-1.72	81.58	84.69	0.28
20	8.88	51.02	50.78	18.68	-5.47	-2.70	64.23	67.00	0.24
30	7.25	42.65	42.40	15.26	-5.[illegible]1	-2.90	52.60	55.02	0.25
40	6.11	36.38	36.11	12.84	-4.94	-2.83	44.28	46.39	0.27
50	5.26	31.53	31.25	11.05	-4.53	-2.68	38.05	39.90	0.28

2OCT0063 N0=320.00 GMR= 8.31 DN= 48.14 DNP= 37.62 N9P=105.13

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	14.64	79.89	79.55	29.84	-1.41	1.47	108.32	111.20	0.33
10	10.46	63.18	62.83	21.32	-4.41	-1.49	80.10	83.02	0.35
20	8.31	51.58	51.24	16.94	-4.94	-2.33	63.58	66.20	0.35
30	6.87	43.15	42.80	13.99	-4.84	-2.54	52.30	54.60	0.35
40	5.82	36.81	36.46	11.85	-4.53	-2.52	44.13	46.14	0.35
50	5.03	31.90	31.56	10.24	-4.18	-2.40	37.97	39.74	0.35

2OCT1258 N0=340.20 GMR= 9.48 DN= 73.73 DNP= 60.37 N9P=106.00

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	18.34	79.06	78.48	39.74	0.02	3.11	118.81	121.90	0.58
10	12.72	62.04	61.38	27.57	-5.45	-2.15	84.16	87.47	0.67
20	9.48	50.64	49.95	20.54	-6.05	-3.14	65.13	68.04	0.69
30	7.62	42.39	41.71	16.50	-5.78	-3.26	53.11	55.63	0.68
40	6.37	36.17	35.52	13.79	-5.33	-3.13	44.63	46.82	0.65
50	5.46	31.36	30.75	11.82	-4.86	-2.93	38.32	40.24	0.61

3OCT0062 N0=331.60 GMR= 8.83 DN= 55.89 DNP= 52.90 N9P=105.81

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	16.06	81.03	80.17	33.91	-1.06	1.99	113.88	116.93	0.85
10	11.46	63.99	63.04	24.20	-4.90	-1.77	83.29	86.43	0.96
20	8.83	52.31	51.31	18.64	-5.45	-2.65	65.50	68.30	1.01
30	7.21	43.79	42.81	15.21	-5.28	-2.83	53.73	56.18	0.98
40	6.08	37.36	36.45	12.83	-4.91	-2.77	45.28	47.42	0.92
50	5.24	32.38	31.54	11.06	-4.52	-2.63	38.92	40.81	0.85

3OCT1263 NØ=329.10 GMR= 8.47 DN= 42.49 DNP= 44.57 N9P=105.44

BØ	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
Ø	11.72	82.66	81.98	24.56	-2.51	Ø.63	104.71	107.85	Ø.68
1Ø	1Ø.51	65.27	64.66	22.Ø2	-4.57	-1.48	82.73	85.82	Ø.61
2Ø	8.47	53.22	52.61	17.76	-5.17	-2.39	65.81	68.59	Ø.61
3Ø	7.Ø3	44.47	43.86	14.72	-5.Ø8	-2.64	54.11	56.55	Ø.6Ø
4Ø	5.97	37.89	37.31	12.5Ø	-4.77	-2.63	45.62	47.76	Ø.58
5Ø	5.17	32.81	32.27	1Ø.82	-4.4Ø	-2.52	39.23	41.11	Ø.55

4OCTØØ63 NØ=335.4Ø GMR= 8.82 DN= 49.89 DNP= 41.73 N9P=1Ø4.96

BØ	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
Ø	16.13	82.Ø3	81.79	34.46	-1.12	2.Ø1	115.37	118.5Ø	Ø.24
1Ø	11.Ø7	64.57	64.32	23.65	-4.85	-1.64	83.37	86.59	Ø.25
2Ø	8.82	52.51	52.28	18.84	-5.49	-2.62	65.86	68.73	Ø.23
3Ø	7.28	43.82	43.58	15.54	-5.38	-2.87	53.97	56.48	Ø.24
4Ø	6.16	37.32	37.Ø7	13.14	-5.Ø4	-2.85	45.43	47.62	Ø.26
5Ø	5.31	32.31	32.Ø5	11.34	-4.63	-2.71	39.Ø2	4Ø.94	Ø.26

4OCT1258 NØ=327.8Ø GMR= 8.83 DN= 61.61 DNP= 51.13 N9P=1Ø5.6Ø

BØ	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
Ø	2Ø.18	78.86	78.58	42.14	1.7Ø	4.37	122.69	125.37	Ø.29
1Ø	11.76	62.39	61.78	24.55	-4.94	-1.88	82.ØØ	85.Ø7	Ø.61
2Ø	8.83	51.Ø3	5Ø.35	18.44	-5.41	-2.69	64.Ø6	66.78	Ø.68
3Ø	7.18	42.72	42.Ø6	14.98	-5.21	-2.84	52.49	54.86	Ø.66
4Ø	6.Ø4	36.46	35.84	12.6Ø	-4.84	-2.76	44.22	46.3Ø	Ø.62
5Ø	5.2Ø	31.61	31.Ø3	1Ø.85	-4.44	-2.61	38.Ø2	39.84	Ø.58

5OCTØØ57 NØ=311.6Ø GMR= 7.99 DN= 44.83 DNP= 42.6Ø N9P=1Ø4.8Ø

BØ	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
Ø	15.33	79.18	78.69	3Ø.42	-Ø.93	1.76	1Ø8.66	111.36	Ø.49
1Ø	1Ø.Ø8	62.91	62.33	2Ø.ØØ	-4.16	-1.39	78.75	81.51	Ø.58
2Ø	7.99	51.5Ø	5Ø.91	15.86	-4.63	-2.14	62.74	65.23	Ø.6Ø
3Ø	6.61	43.16	42.57	13.12	-4.53	-2.34	51.75	53.94	Ø.59
4Ø	5.62	36.85	36.28	11.14	-4.25	-2.32	43.75	45.67	Ø.57
5Ø	4.87	31.96	31.42	9.65	-3.92	-2.22	37.68	39.38	Ø.54

1NOV1255 N0=339.20 GMR= 9.26 DN= 65.09 DNP= 45.40 N9P=106.00

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	14.49	80.21	79.84	31.30	-1.91	1.36	109.59	112.87	0.37
10	11.82	62.69	62.54	25.53	-5.15	-1.86	83.08	86.36	0.15
20	9.26	50.95	50.86	20.00	-5.87	-2.96	65.08	67.99	0.08
30	7.53	42.54	42.44	16.26	-5.68	-3.16	53.12	55.65	0.10
40	6.32	36.25	36.12	13.65	-5.26	-3.07	44.63	46.83	0.13
50	5.43	31.40	31.25	11.72	-4.81	-2.89	38.30	40.23	0.14

2NOV0063 N0=340.60 GMR= 9.15 DN= 57.87 DNP= 33.51 N9P=105.64

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	16.57	81.26	81.30	35.96	-1.02	2.19	116.19	119.41	-0.04
10	11.49	63.59	63.75	24.92	-5.07	-1.75	83.44	86.76	-0.16
20	9.15	51.56	51.79	19.84	-5.80	-2.85	65.60	68.55	-0.23
30	7.50	42.97	43.17	16.28	-5.67	-3.11	53.58	56.14	-0.20
40	6.32	36.57	36.72	13.71	-5.28	-3.05	45.00	47.23	-0.15
50	5.44	31.65	31.75	11.79	-4.84	-2.89	38.61	40.56	-0.10

2NOV1261 N0=345.20 GMR= 9.05 DN= 46.55 DNP= 42.70 N9P=105.64

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	11.35	83.80	83.91	24.96	-2.94	0.53	105.82	109.29	-0.11
10	10.91	65.42	65.86	23.99	-4.97	-1.56	84.45	87.85	-0.43
20	9.05	52.87	53.41	19.90	-5.79	-2.74	66.98	70.03	-0.54
30	7.52	43.95	44.45	16.53	-5.73	-3.07	54.75	57.41	-0.50
40	6.37	37.34	37.76	14.00	-5.37	-3.06	45.96	48.27	-0.42
50	5.50	32.27	32.62	12.07	-4.94	-2.92	39.40	41.42	-0.35

3NOV0063 N0=314.20 GMR= 7.97 DN= 39.72 DNP= 37.83 N9P=104.87

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DR1	ERROR
0	15.68	80.22	79.96	31.39	-0.83	1.90	110.79	113.52	0.27
10	10.04	63.80	63.35	20.09	-4.19	-1.37	79.71	82.52	0.46
20	7.97	52.20	51.69	15.94	-4.64	-2.10	63.50	66.04	0.50
30	6.62	43.67	43.19	13.25	-4.56	-2.32	52.36	54.60	0.48
40	5.64	37.24	36.79	11.28	-4.29	-2.33	44.23	46.20	0.45
50	4.89	32.26	31.85	9.78	-3.97	-2.24	38.08	39.81	0.42

3NOV1234 N0=321.10 GMR= 8.29 DN= 45.24 DNP= 47.54 N9P=105.14

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	12.51	80.73	80.21	25.58	-2.14	0.82	104.17	107.14	0.52
10	10.33	63.82	63.37	21.12	-4.38	-1.44	80.56	83.50	0.46
20	8.29	52.10	51.65	16.95	-4.94	-2.30	64.11	66.75	0.45
30	6.86	43.57	43.13	14.02	-4.84	-2.52	52.75	55.07	0.44
40	5.82	37.15	36.72	11.89	-4.54	-2.50	44.50	46.54	0.43
50	5.04	32.18	31.78	10.29	-4.19	-2.40	38.28	40.07	0.40

4NOV0031 N0=316.60 GMR= 8.21 DN= 48.03 DNP= 42.06 N9P=104.09

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	15.39	79.18	79.00	31.04	-1.02	1.77	109.20	111.99	0.18
10	10.40	62.71	62.45	20.97	-4.33	-1.48	79.35	82.21	0.26
20	8.21	51.24	50.97	16.55	-4.83	-2.27	62.96	65.52	0.27
30	6.78	42.87	42.60	13.66	-4.72	-2.47	51.80	54.05	0.27
40	5.75	36.56	36.30	11.58	-4.42	-2.45	43.72	45.69	0.26
50	4.97	31.68	31.43	10.01	-4.08	-2.34	37.61	39.35	0.25

4NOV1256 N0=312.20 GMR= 8.07 DN= 47.53 DNP= 39.00 N9P=102.73

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	13.04	78.44	78.35	25.94	-1.80	0.99	102.58	105.37	0.09
10	10.10	62.07	62.01	20.09	-4.17	-1.40	77.98	80.75	0.05
20	8.07	50.69	50.65	16.04	-4.68	-2.19	62.04	64.53	0.03
30	6.67	42.41	42.36	13.26	-4.58	-2.40	51.08	53.27	0.04
40	5.66	36.17	36.11	11.25	-4.30	-2.38	43.12	45.04	0.06
50	4.90	31.34	31.28	9.73	-3.96	-2.27	37.11	38.80	0.06

5NOV0037 N0=311.20 GMR= 7.90 DN= 40.65 DNP= 36.01 N9P=100.36

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	13.52	79.27	79.30	26.79	-1.63	1.13	104.44	107.19	-0.03
10	9.81	62.88	62.87	19.45	-4.07	-1.31	78.26	81.01	0.01
20	7.90	51.35	51.34	15.65	-4.56	-2.07	62.45	64.93	0.02
30	6.58	42.94	42.92	13.03	-4.49	-2.30	51.48	53.67	0.02
40	5.60	36.60	36.57	11.09	-4.23	-2.30	43.47	45.39	0.02
50	4.86	31.70	31.67	9.62	-3.91	-2.21	37.40	39.10	0.03

1DEC1250 N0=340.60 GMR= 8.87 DN= 44.37 DNP= 30.70 N9P=107.04

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	10.37	83.61	83.53	22.51	-3.01	0.37	103.10	106.48	0.07
10	10.56	65.37	65.66	22.91	-4.78	-1.46	83.50	86.82	-0.29
20	8.87	52.88	53.30	19.23	-5.59	-2.62	66.51	69.49	-0.42
30	7.39	44.00	44.37	16.02	-5.55	-2.96	54.47	57.07	-0.37
40	6.26	37.42	37.71	13.58	-5.21	-2.95	45.79	48.05	-0.29
50	5.41	32.37	32.59	11.72	-4.79	-2.81	39.29	41.27	-0.22

2DEC0059 N0=351.90 GMR= 9.42 DN= 54.32 DNP= 47.43 N9P=106.38

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	13.84	83.90	83.69	31.03	-2.44	1.11	112.48	116.03	0.21
10	11.71	65.48	65.47	26.25	-5.33	-1.79	86.40	89.94	0.00
20	9.42	52.99	53.06	21.12	-6.16	-3.00	67.95	71.11	-0.06
30	7.75	44.10	44.13	17.37	-6.04	-3.30	55.42	58.17	-0.04
40	6.54	37.49	37.49	14.64	-5.63	-3.25	46.50	48.88	0.00
50	5.63	32.42	32.39	12.60	-5.17	-3.09	39.85	41.94	0.04

2DEC1263 N0=365.80 GMR= 9.72 DN= 47.86 DNP= 32.84 N9P=106.30

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	11.54	86.90	86.91	26.90	-3.37	0.53	110.43	114.33	-0.00
10	11.60	67.41	67.83	27.04	-5.55	-1.71	88.89	92.73	-0.43
20	9.72	54.21	54.79	22.65	-6.58	-3.15	70.28	73.71	-0.58
30	8.07	44.95	45.46	18.80	-6.53	-3.56	57.21	60.19	-0.52
40	6.82	38.13	38.54	15.88	-6.12	-3.54	47.90	50.47	-0.41
50	5.87	32.94	33.26	13.67	-5.61	-3.37	40.99	43.23	-0.32

3DEC0061 N0=358.60 GMR= 9.96 DN= 69.36 DNP= 56.41 N9P=106.05

B0	GM	DR1P	DR1S	DR2	DR3	DR31	DR39	DRI	ERROR
0	17.97	82.35	82.17	41.04	-0.71	2.80	122.68	126.19	0.18
10	12.91	64.09	64.00	29.50	-5.84	-2.15	87.75	91.43	0.08
20	9.96	51.90	51.86	22.74	-6.67	-3.41	67.98	71.23	0.04
30	8.07	43.22	43.16	18.42	-6.45	-3.64	55.20	58.00	0.06
40	6.75	36.77	36.68	15.42	-5.97	-3.54	46.22	48.65	0.09
50	5.79	31.81	31.70	13.21	-5.45	-3.32	39.58	41.70	0.12

3DEC1256 N0=338.30 GMR= 9.15 DN= 61.51 DNP= 50.87 N9P=107.11

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	15.08	80.73	80.31	32.49	-1.66	1.57	111.56	114.80	0.43
10	11.74	63.30	62.97	25.30	-5.11	-1.84	83.50	86.76	0.33
20	9.15	51.51	51.20	19.72	-5.78	-2.87	65.45	68.35	0.30
30	7.46	43.02	42.71	16.08	-5.60	-3.08	53.50	56.02	0.31
40	6.28	36.67	36.34	13.51	-5.20	-3.01	44.98	47.18	0.32
50	5.40	31.77	31.44	11.62	-4.77	-2.84	38.62	40.55	0.32

4DEC0063 N0=348.50 GMR= 9.62 DN= 68.45 DNP= 65.00 N9P=106.10

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	14.65	81.04	80.74	32.51	-2.08	1.38	111.47	114.93	0.30
10	12.30	63.08	63.06	27.30	-5.46	-1.99	84.92	88.40	0.02
20	9.62	51.14	51.20	21.35	-6.27	-3.20	66.23	69.30	-0.06
30	7.81	42.64	42.67	17.33	-6.07	-3.42	53.91	56.56	-0.03
40	6.54	36.31	36.30	14.51	-5.61	-3.32	45.22	47.51	0.02
50	5.61	31.45	31.39	12.44	-5.12	-3.12	38.76	40.77	0.06

4DEC1261 N0=358.90 GMR=10.19 DN= 79.11 DNP= 68.80 N9P=106.80

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	18.16	80.89	80.48	41.53	-0.59	2.91	121.83	125.33	0.42
10	13.50	62.85	62.58	30.87	-6.03	-2.34	87.68	91.37	0.26
20	10.19	50.99	50.76	23.28	-6.86	-3.62	67.41	70.65	0.22
30	8.17	42.53	42.29	18.67	-6.57	-3.78	54.63	57.42	0.24
40	6.81	36.22	35.97	15.55	-6.04	-3.63	45.74	48.14	0.25
50	5.82	31.36	31.10	13.30	-5.49	-3.39	39.17	41.27	0.26

5DEC0063 N0=309.40 GMR= 7.77 DN= 36.93 DNP= 39.72 N9P=106.70

B0	GM	DR1P	DR1S	DR2	DR3	DR3I	DR39	DRI	ERROR
0	11.27	80.28	79.59	22.22	-2.19	0.57	100.30	103.07	0.69
10	9.52	63.81	63.18	18.75	-3.96	-1.23	78.61	81.34	0.63
20	7.77	52.23	51.60	15.31	-4.45	-1.99	63.08	65.55	0.63
30	6.48	43.76	43.13	12.77	-4.39	-2.21	52.14	54.32	0.62
40	5.53	37.35	36.75	10.89	-4.14	-2.22	44.11	46.02	0.60
50	4.80	32.39	31.82	9.45	-3.83	-2.14	38.01	39.70	0.57